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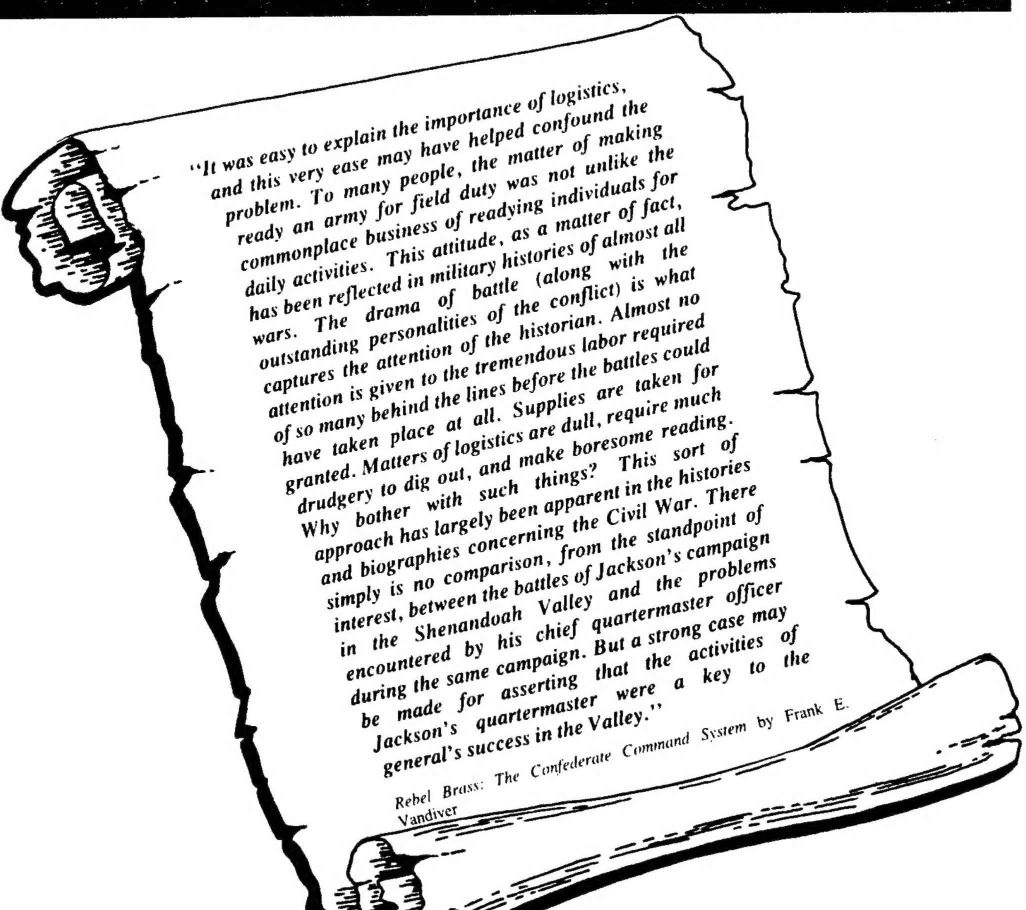

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Logistics Research - "The Unsilent Partner"

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Introduction

Logistics support and the bigger issue of weapons system availability have been with us from the beginning of the world. From the time the first rock was thrown in anger, to our current complex weapons system employment, the mission of the logistician remains basically unchanged—to provide the right mix of weapons systems, at the right time, in the right place, in the right numbers, and in operating condition to support the commander's plan of attack. In Neolithic times, the fundamental role of the logistician might have been simply to collect sufficient rocks and clubs and distribute them to the warriors to allow the battle to be fought on what the commander perceived to be a favorable advantage. Reliability and maintainability were characteristics applied to the warrior—not his weapons. Rocks and clubs were inert things. How they were employed and with what speed and accuracy were the foundations of the warrior's perception of advantage. What has changed over the centuries is that perception of advantage which, to a large degree, has driven technology deep into the mind-set of warriors.

The application of technology to the war-fighting arena stems primarily from the warrior's perception of advantage. This common theme can be illustrated in dramatic historical technological examples, such as the stirrup, the long bow, the first blunderbuss, the rifle, the machine gun, the tank, and ultimately the aircraft. The key logistics message is the added complexity that the logistician must now face to execute the unchanged mission. In less than 100 years, we have seen the speed of the warrior move from the slow pace of the horse, early locomotives, and sailing ships to the rapid pace of the circumnavigation of the earth in less than 90 minutes, or to geosynchronous satellites that could bring large parts of our world under continuous real-time threat. The traditional methods of providing logistics support can no longer evolve arithmetically but must match the pace of the warrior's technological advantage. As has been stated by an experienced Pentagon general, "In making war, amateurs talk about tactics. The real professionals talk about logistics and sustainability because that is where wars are won."[1]

Key Components of the Logistics R&D Program

> ***"Using a 20-year forecast, the Air Force logistics LRP provides broad planning guidance to develop future capabilities. Five planning goals have been developed to shape our logistics posture throughout this planning period."***

The Air Force logistics research and development (R&D) program is a major attempt to use technology to apply lessons learned from past experiences to current situations and to take advantage of future opportunities. The program, administered by the Air Force Coordinating Office for Logistics Research (AFCOLR), is comprised of a number of key components which interact to form a viable whole.[2]

Logistics long-range planning (LRP) is the umbrella under which the logistics R&D program components operate. One definition used for logistics LRP is: "A systematic process of formulating goals and objectives for the future and then developing the necessary plans and programs for reaching them."[3] Using a 20-year forecast, the Air Force logistics LRP provides broad planning guidance to develop future capabilities. Five planning goals have been developed to shape our logistics posture throughout this planning period:[4]

(1) Organize wartime operations and conduct peacetime operations within that framework.

(2) Develop a logistics capability postured to support United States (US) forces engaged in varying levels of conflict either independently or in concert with other friendly nations.

(3) Include logistics at the forefront of all Air Force contingency planning and weapons system design.

(4) Develop a better means to identify and assess logistics requirements and capability, especially those that relate to execution of US contingency plans.

(5) Effectively manage or influence the management of scarce logistics resources to maintain Air Force combat capability.

These goals are translated into specific objectives, a few of which will be reviewed in terms of new technology potential in resolving problems or meeting future opportunities. In the area of weapons system supportability, a number of the objectives require the research and development approach for finding solutions to logistics problems. The following examples are provided from the current draft of the *USAF Logistics Long-Range Planning Guide*:[5]

Objective: Provide weapons systems with logistics design characteristics that meet war-fighting requirements.

- Increase the emphasis on supportability and reliability in weapons system design and modification.
- Design future weapons systems to accommodate growth and modifications.

Objective: Make logistics supportability an acquisition criterion equal in importance to cost, schedule, and performance.

Objective: Improve the productivity of organic operations to support wartime requirements.

- Evaluate evolving repair technologies for specific logistics application.
- Design end items for repair during the acquisition cycle.

Objective: Develop the logistics capabilities to deploy and sustain combat forces in varied types of war scenarios.

- Design logistics equipment to minimize transportation requirements.
- Enhance airlift and sealift capability.
- Improve the capability of logistics to function in an austere environment.
- Design equipment to minimize shipment preparation and set-up time.
- Improve systems and procedures to prepare, maintain, and protect prepositioned resources.

In line with the Air Force's long-range planning objectives, the logistics R&D requirements program is annually initiated with a "call to the field" by the Air Force Deputy Chief of Staff, Logistics and Engineering (HQ USAF/LE). This call provides an opportunity for the major commands, separate operating agencies, and Air Staff organizations to input logistics oriented research and development requirements (logistics needs) into the research base. The Air Force Acquisition Logistics Division (AFALD), the Air Force Logistics Command (AFLC), and AFCOLR are all fundamental and vital elements of the Air Force logistics R&D program. They each influence one another's actions and capabilities and play a big part in defining research and logistics issues. For the purposes of this article, logistics oriented research is:[6]

> A systematic inquiry of significant scope centered on areas of long-standing problems and future opportunity for the logistics community. The objective is to enhance the system's effectiveness and efficiency, and expand professional knowledge and understanding. Logistics oriented research encompasses an examination of the logistics processes and their interactions with the external environment and with each other; development and application of technology with the logistics system; and development and application of technology to weapon systems and material, with the express purpose of enhancing supportability.

Once the requirements have been identified, they are then forwarded to AFCOLR, where individual organization submissions are collected, assembled, consolidated (where possible), and integrated (as required) into an Air Force package. After appropriate processing within the logistics community, the package of logistics R&D requirements is forwarded by HQ USAF/LE to the Air Force Systems Command (AFSC) Vice Commander for formal insertion into their laboratories' planning and programming cycles—their own Program Objective Memorandum (POM) development.

The Logistics Research and Technical Training Division Laboratory, part of the AFSC Human Resources Laboratory (HRL) structure, is another major component of the program. This laboratory performs human factors, management science, and operations research R&D which in turn complements work in the hardware and physical sciences laboratories. To enhance coordination, AFCOLR and the laboratory division are collocated at Wright-Patterson Air Force Base, Ohio.

Another key component is the technology transition function. While this function is not part of research per se, the identification of a specific user and assigned responsibility for application of research results closes the loop for research opportunities. A logical grouping of these functions by responsibility follows:

Logistics User Primary Responsibility:

- Identify and articulate logistics research needs.
- Evaluate research results.
- Apply research results.

Researcher Primary Responsibility:

- Define specific research projects.
- Identify, justify, and advocate funds.
- Perform research.

AFCOLR Responsibility:

- Perform broker role to link buyers (users) and sellers (research base).
- Maintain central knowledge base on logistics R&D.
- Develop coordinated technology transition plans.

To establish and institutionalize these functions further, the management structure, process, and dollars required for a comprehensive logistics oriented R&D program were further enhanced by the recent establishment of two new program elements. This action was in response to direction provided by the Office of the Under Secretary of Defense, Research and Engineering, and the Assistant Secretary of Defense for Manpower, Reserve Affairs & Logistics. A short description of the new program elements is found in a HQ USAF/LEX letter, Logistics R&D Program:[7]

> A 63XXX program element within the technology base will provide management structure for dealing with reliability, maintainability, design, and support concept technology which spans two or more laboratories. The program element will be monitored by AF/RD and executed through a SYSTO and program manager system with AFSC. A program element at 6.4 is required to develop and demonstrate selected potential high payoff support technology. Applications will be evaluated in parallel with baseline SPO efforts and integrated as part of the Preplanned Product Improvement Program (P^3I). Such a technology transfer program element will provide the mechanism, management direction, and funding which will insure demonstration of technology applications for improving weapon system support without initial dependence on the supported system program.

In addition to influencing the Air Force laboratories to increase their levels of defined logistics/supportability oriented research, management will place additional attention on communicating supportability requirements to industry through Statements of Work (SOWs), Statements of Need (SONs), Justification for Major System New Starts (JMSNSs), and Requests for Proposals/Quotations (RFPs/RFQs). Goal 9, "Superior Weapon Systems," from the *Corporate Guidance for Air Force Systems Command,* is quoted as an example:[8]

> Insure proper trade-offs are made between performance, new technology, reliability and supportability to maximize weapons systems effectiveness and minimize life cycle costs.
>
> Improve readiness through:
>
> - Simply operated and repairable systems.
> - Weapon systems with reduced manpower requirements.
> - Higher levels of reliability and product assurance.
> - Enhanced maintainability.
> - Improved logistics support systems.
> - Adequate wartime and emergency reserves.
> - Responsive industrial backup capability.
>
> Develop test measures of effectiveness to evaluate how well new weapon systems meet performance specifications, supportability goals, and system readiness objectives.

A lot of work remains to perfect this goal which ensures logistics requirements are incorporated during the earliest phase of weapons system design.

Another key component of the Air Force logistics R&D program is the role industry plays in achieving logistics objectives by emphasizing supportability research in their Independent Research and Development (IR&D) programs. Dr. Richard D. DeLauer, Under Secretary of Defense for Research and Engineering (USDR&E), expressed the urgent need for IR&D support of logistics requirements in his 1

March 1982 Memorandum for the Assistant Secretaries of the Army, Navy, and Air Force.[9]

> Technical innovation is essential to improving the readiness of our next generation weapons and reducing their logistics and manpower burdens. Weapon support characteristics have reached such levels of importance that we can no longer let them "just happen" after performance objectives have been satisfied. Greater effort must be applied to make technology available which can be used to increase mission reliability, reduce dependence on support equipment, and reduce the support tail, spares and repair facilities, and, equally important, reduce the need for highly skilled personnel. The impetus to shorten acquisition time requires that much of the technology used be on-the-shelf.
>
> Industry must play a major role in achieving our objectives by emphasizing these technologies in their IR&D programs.

"In the past, logistics oriented IR&D has been, for all practical purposes, nonexistent."

In the past, logistics oriented IR&D has been, for all practicable purposes, nonexistent. There were several reasons for industry's reluctance to fund logistics related IR&D. Because relatively little logistics oriented research funds were expended by the Air Force or DOD, industry perceived that logistics IR&D was of little interest. This perception was reinforced by a lack of logistics representation on Air Force IR&D review teams and a lack of published logistics research needs.

In 1982, the AFCOLR was appointed the logistics focal point for IR&D in the Air Force.[10] One of its first initiatives provided industry with a compendium of Air Force logistics R&D programs and needs. By April 1982, over 400 major DOD contractors had received the *FY 1982 Air Force Logistics Research and Studies Program* document. This document, the first of its kind, will be refined, updated, and distributed annually. In addition, AFCOLR is currently receiving industry IR&D technical plans and is reviewing and grading the supportability issues. Also key experts throughout the logistics community are being identified and added to evaluation teams conducting contractor on-site reviews. The Air Force is continuing to spread the word that supportability equals cost, schedule, and performance through papers, symposiums, professional societies, and industrial associations. There is significant recent evidence that contract IR&D programs are beginning to reflect substantial increases in logistics oriented research projects.[11]

Implications for the Future

For the Air Force planner, the future holds a dynamic and challenging environment, not only in the areas of technology and the changing threat, but how to meet those challenges in the face of critical manpower and strategic material shortages. Foremost in the planner's thinking is the knowledge that:[12]

> Support requirements have evolved from the design characteristics and employment strategies of the weapon systems being supported. Weapon system designs have led to support processes characterized by manpower and equipment intensity. The presently large, highly industrialized, and relatively immobile support structure reflects the support-dependence of current weapon systems. If not reduced, combat dependence on this vulnerable, fixed-site support structure may prove to be a limiting factor to effective employment of 21st century air power.

The unpredictable timing and location of future conflicts; vulnerability of airlift and sealift; disruption of command, control, and communication; and reduced sanctuary of air bases are a few of the challenges that will also have to be addressed.[13]

"The most critical operational support characteristic needed to ensure sustainability of war-fighting forces is survivability."

In the *Air Force 2000* study, three major characteristics were identified as essential to the 21st century operational support structure—mobility, flexibility, and survivability—essential elements to enhance combat effectiveness in a global war-fighting environment. The support structure will have to be as mobile as the inherent mobility and maneuverability of the weapons systems it supports. In order to sustain combat forces across the full range of potential conflict, a flexible operational support system will be required. The most critical operational support characteristic needed to ensure sustainability of war-fighting forces is survivability.[14]

The implications of this future environment quickly point to a quagmire of conflicting needs and requirements for the Air Force planner. For example, to ensure future readiness and sustainability, sufficient quantities of spares, support equipment, munitions, fuels, etc., and the trained manpower to use them must be readily available under a tree in South Yemen, or next to a bale of hay in Argentina, or wherever our rapid deployment forces are tasked to go. The dilemma arises not only in determining how to get the materials, equipment, and people to the deployed location in time to sustain operations, but also raises the questions of where the projected shortages in trained manpower, energy (fuels), and strategic materials (engines) originate. Once in place, how will these support entities function in projected chemical, biological, and radioactive environments, and how will they be sustained in terms of dedicated logistics command, control, communication, and assured distribution?

It quickly becomes apparent that the planner is going to need substantial help in developing a viable support posture for complex weapons systems deployed to an out-of-the-way location in response to some unexpected crisis. This is where supporting technology (logistics R&D) must lend a helping hand. By innovating design and developing new support concepts, the research base can offer ways to reduce the support burden and manpower skill requirements associated with complex weapons systems. In support of this position, the Air Force's weapons system support concept for the year 2000 emphasizes three major dimensions:[15]

(1) Enhanced weapons system supportability, achieved by exploiting technology for reliability, maintainability, and suitability.

(2) A production oriented, decentralized weapons system maintenance, accomplished by distinguishing between on-equipment and off-equipment maintenance processes.

(3) An improved logistics resourcing process, achieved through more effective requirements, determination capabilities, and management and distribution systems.

The Air Force logistics long-range planning effort has been described along with a discussion of its major logistics research elements. The objectives that must be met have been made clear. What remains is a transition from this description

of programs and elements into a clear example of how the warrior's advantage *can be* enhanced in the 21st century in terms of a specific weapons system—the advanced tactical fighter (ATF).

The Warrior's Advantage in the 21st Century: The Advanced Tactical Fighter

The advanced tactical fighter (ATF) is a weapons system being conceived by the Air Force to meet the threat envisaged in the 21st century. The logistics community must also recognize the threat and develop a parallel concept that demands quantum leaps in reliability and maintainability in the ATF. These two key drivers must be seated in logistics oriented research and technology application to achieve the mobility, flexibility, and survivability that the threat environment will demand of the ATF. What follows is an example of how the Air Force logistics community can come to terms with developing a support concept for application of logistics R&D to "fly in formation" with the weapons system R&D program. This example is aimed at maintenance and maintainers, but it does not discount other elements of the logistics force structure such as acquisition, requirements computation, assured distribution, and facilities. It does recognize that these two key support functions will always deploy with the warrior and as such represent either substantial constraints or benefits to the warrior's advantage in some remote corner of our world.

Engineering data, from which maintenance documentation is derived, is fundamental to any support concept design approach and is the technique that is responsible for the who, how many, skill levels, training, and responsiveness needed. This data has been historically ill-defined, badly produced, and bought several times. Presently, our maintenance documentation involves millions of pages, put together in binders called technical orders (TOs). It is developed, printed, and purchased for billions of dollars and distributed throughout the world because one *might need to use it* when a maintenance event occurs. Such events run from normal servicing to complicated unscheduled maintenance.

Today, there is a great opportunity to shift from this costly system for an event-driven access to a live, interactive data base system that will allow the maintainer to tap the data base only when an event occurs. Coupled with this shift is the opportunity to build a digital distributed network that will allow near real-time update of the technical data base anywhere in the world through the most survivable communication links—the satellite and/or ground based packed switch networks. Both interactive data bases and digital distributed networks are validated technologies today.

Exploding electronics and integrated circuits technology represent another fertile area where logistics related R&D holds great promise for enhancing the warrior's advantage. There are three key elements to this initiative:

(1) **Built-in diagnostics.** This element involves built-in test/fault isolation test (BIT/FIT) capabilities. Validated and near-validated technology, available in large-scale integrated circuits and very high speed integrated circuits (VHSIC), provides the opportunity to design unimaginable increases in reliability and maintainability into the ATF.

(2) **Graceful degradation.** Quantum leaps in reliability will come with this element which involves digital signal processing and redundancy that will allow a system to degrade without the warrior perceiving any degradation of system performance. The maintainer will sense it through on-board recorders and test circuits, but the maintenance urgency of a grounded aircraft will have been removed. Quantum leaps in maintainability will be achieved by a combination of on-board systems tied to the live data base that will direct the maintainer to the exact problem and make troubleshooting an antiquated term. The combination of an interactive data base, tied to on-board diagnostics, can nearly eliminate prolonged troubleshooting sequences that plague current weapons systems today.

(3) **Transparent technology.** This element is a combination of the application of the first two elements and adds the human to the equation. User friendly diagnostics, coupled with live data bases and man's inherent flexibility, will make the complexity of highly sophisticated systems "transparent," promoting generalized rather than specialized maintenance skills. This shift from specialists to generalists promises huge manpower and support base reductions.

All of these elements combined, i.e., interactive data bases, on-board diagnostics, digital distributed networks, BIT/FIT, VHSIC, graceful degradation, and transparent technology, can enhance the warrior's advantage. If they are not pursued and the ATF is supported in a traditional mode, the warrior will experience severe constraints.

There is another area that promises great improvements—support equipment. Today's weapons systems require an entourage of ground support equipment from avionics intermediate test sets to liquid oxygen plants. These requirements tie the warrior to a fixed infrastructure base or demand huge amounts of strategic airlift to move this support tail and associated people to the employment location. There is validated or near-validated technology available today that could dramatically reduce or eliminate portions of this support tail burden. Multifunctional integrated power units could be available on board the ATF that would eliminate ground starting units, generators, and other support equipment. Kidney dialysis technology provides the opportunity to split free air into breathing oxygen and inert gas that could be channeled into fuel systems as a fire suppressant. This combination system could be on board the aircraft at very little weight penalty and eliminate the need for liquid oxygen and liquid nitrogen.

The bottom line in these examples is a demand that validated technologies, available today or certainly potentially available, be driven into the front-end design by the using command and the logistics community. The promise of huge payoffs in reliability and maintainability improvements, not to mention enormous impacts on life cycle cost, is far too great to ignore. These examples are ingrained in the very essence of *Air Force 2000* in terms of logistics initiatives to enhance the warrior's advantage.[16] It is time for the new senior partner to speak out. If he does not, the warrior's advantage in the 21st century will literally be vetoed by perpetuating historical logistics support practices.

"The crucial future issue is to 'close the sale.'"

Conclusions

The case has been made for a senior partner's chair for logistics research in the overall Air Force R&D long-range

planning corporate structure. What, then, remains to be done? The crucial future issue is to "close the sale." This expression is taken from the life insurance industry. It means, very simply stated, that the customer who has recognized the risk and asked for an estate plan (risk coverage) and who is not contemplating a decision to commit scarce financial resources to this plan must now sign or decline. The successful agent has, through training and experience, developed a unique talent to "close the sale." This does not mean a simple signature that the customer may elect to withdraw during the legal grace period designed to counter high pressure sales tactics. It means walking away with a signed contract that will not be withdrawn because the customer is convinced that the risk is too great to ignore. The military analogy is clear. While the insurance customer weighs his decision against feeding, housing, clothing, and educating his family, the warrior weighs his decision against weapons system cost, schedule, and performance. Today, the warrior's decision is further complicated by the 21st century threat. He must think in terms of detached issues such as air field survivability, chemical warfare, vulnerable lines of communication, and sustainability and survivability of his forces.

The logistics community must "close the sale" with the R&D, operations, plans, manpower, contractor, and DOD communities. Without this institutionalized link, supportability has little chance of being transformed from rhetoric into reality. What is common to both the customer and the warrior is one basic fact. Neither one will see any short-term return on investment—a demand that has been instilled in our society for over 20 years. Mr. Reginald Jones, the recently retired Chairman of the Board of General Electric, best described this societal evolution and its impact on US industry:

> We have consciously sought to elevate the lawyer and accountant to the Chief Executive Office (CEO) positions of our corporations. By doing this, we have brought a short-term return on investment strategy to our corporate structures. This strategy demands an improvement on this quarter [1982] versus last year's quarter. It stifles growth and capital investment and is killing us in the international marketplace.[17]

The Department of Defense (DOD) inherited the same strategy during the tenure of Robert McNamara as Secretary of Defense. Over the years, this strategy has permeated DOD in terms of the Planning, Programming, and Budgeting System (PPBS). This deeply ingrained short-term return on investment mind-set must be weighed heavily when considering any logistics strategy to "close the sale."

The strategy required to execute the transition from supportability (readiness and sustainability) rhetoric to reality must be aggressively marketed by the logistics community and contain the following elements:

(1) Continued improvement in the integration of logistics long-range planning with the Air Force and Joint Chiefs of Staff programs.

(2) Development of an awareness and commitment on the part of the using commands that the SON must drive the weapons system concept in terms of supportability. The SONs need to demand that validated and potentially available logistics related technologies be inserted into the concept development phase of any weapons system. To do this, they must be aware of the technologies and trust the system to produce those technologies.

(3) Development of a logistics force structure that complements and enhances the warrior's advantage in the 21st century threat environment.

(4) Development of a system of integrating logistics concerns in the very early stages of weapons system design. This must be done in such a way that the design engineer is fully cognizant of what supportability means in terms of engineering discipline. It must also be presented in contractual terms that can be measured, traded off logically, and enforced. This is the one single issue that the logistician must articulate much better than in the past.

(5) Continued commitment to develop a logistics R&D program that "flies in formation" with weapons system R&D. This means that both programs are planned and funded together with logistics R&D as a senior partner.

(6) Insertion of logistics as a major measurement criteria for contractor IR&D plan review and evaluation. This seed money expended by contractors to enhance their competition position in the marketplace will not be driven to logistics objectives unless supportability is a major consideration in determining the level of reimbursement by the US government.

(7) Development of a "push-pull" financial and information avenue for transition of validated technology into new weapons systems and retrofit of existing systems. The avenue must be two lanes. The first lane must provide a clear financial vehicle to push and fund transition from the laboratories into weapons systems. The second lane must provide an information mechanism to develop advocacy within the user commands to pull technology out of the laboratories.

The bottom line is: the sale must be closed and institutionalized or we run the risk of repeating the errors rife in logistics history.

Notes

[1]Halloran, Richard. "Defense Department Out To Up Its Staying Power," *Dayton Daily News*, 22 August 1982, p. 9A.

[2]AFCOLR Charter, Wright-Patterson AFB, Ohio, 9 December 1980.

[3]Draft *USAF Logistics Long-Range Planning Guide FY85-99*, HQ USAF/LEXY, 2 August 1982, p. 1.

[4]Ibid., p. 30.

[5]Ibid., pp. 9-16.

[6]SAF/AL Memorandum for HQ USAF/LE and HQ USAF/RD, John J. Martin, Assistant Secretary Research, Development and Logistics, 19 December 1978.

[7]HQ USAF/LEX Letter to AF/PRP, Logistics R&D Program, 8 January 1982.

[8]*Corporate Guidance for Air Force Systems Command*, HQ AFSC, Office of the Commander, February 1981.

[9]USDR&E Memorandum for the Secretaries of the Army, Navy, and Air Force, Increased Readiness and Support, 1 March 1982.

[10]SAF/AL Memorandum for Under Secretary of Defense (Research and Engineering), Increased Independent Research and Development (IR&D) For Improved Weapon System Readiness and Support, 26 May 1982.

[11]Proprietary information and not releasable to non-DOD agencies. Information regarding this subject is available to authorized DOD agencies from AFCOLR, Wright-Patterson AFB, Ohio 45433.

[12]*Air Force 2000: Air Power Entering the 21st Century*, HQ USAF, June 1982, p. 169.

[13]Ibid., pp. 168-169.

[14]Draft *USAF Logistics Long-Range Planning Guide FY85-99*, HQ USAF/LEXY, pp. 2-3.

[15]*Air Force 2000: Air Power Entering the 21st Century*, HQ USAF, June 1982, p. 169.

[16]Ibid., pp. 169, 172, 173, 179.

[17]"Playing It Safe and Losing Out," *Washington Post*, 17 January 1981, p. A-1.

USAF LOGISTICS POLICY INSIGHT

Spare Parts Prices

During the period FY79-82, the Air Force began to investigate the causes for the sharp increases in prices paid for certain spare parts. A series of internal studies and investigations resulted in a public disclosure of an Air Force Logistics Command report on engine spare parts price increases. This disclosure led to a series of congressional hearings and a media blitz which highlighted the issue to the general public.

It was against this backdrop of significant engine spare parts price increases and other price increases that Secretary of the Air Force Verne Orr and Air Force Chief of Staff, General Charles Gabriel, established an Air Force Management Analysis Group (AFMAG) on Spare Parts Acquisition. The AFMAG charter was to look at short-range and long-term actions aimed at improving competition and achieving fair and reasonable prices. The final report which was released on 3 November 1983 contains some 178 recommendations with the overall thrust to: (1) increase competition and (2) buy in economical quantities. The Air Force has established a General Officer Steering Committee at Headquarters USAF, chaired by the Deputy Chief of Staff, Logistics and Engineering, to oversee evaluation of the AFMAG recommendations, promulgate implementation actions, and measure progress of implementation commands and agencies. In parallel with this Committee, the Air Force Inspector General will conduct follow-up inspections to ensure that the desired results are being realized. Many of the long-term recommendations will take several years to implement because they involve changes to DOD regulations and Public Law.

Avionics Systems Support

New avionics systems will be designed with supportability as a prime consideration. System mean time between failure (MTBF) will be increased through use of ultra-reliable very large scale integration (VLSI) with built-in-test (BIT), automatic fault isolation, and fault tolerance capabilities. Flight-line maintenance will be highly automatic, standardized, and integrated. Embedded computer software will be developed in the new DOD standard language, ADA, and will incorporate artificial intelligence (AI) techniques to reduce software change requirements. A major objective is to decrease the need for intermediate level maintenance.

Combat Ammunition System

The Air Force will soon implement a major overhaul of the way that large munitions organizations do business. Specifically, in 1984, those munitions organizations which support combat coded aircraft activity will begin to receive automated data processing equipment needed to operate a self-sufficient automated data system known as the Combat Ammunition System (CAS). The latest in technology, such as laser scanning devices used in industry as well as commercial enterprises, will be applied to all munitions functional areas (munitions control, inspection, supply, storage and handling, nuclear, and missiles) for the purpose of automating almost all manual, labor intensive processes. Examples of munitions functions which will be automated include the inventory process, records (AFTO Form 15), forms creation, data transmittal, storage area planning, munitions assembly and flow planning, and the configuration of munitions into complete rounds. Policy for the CAS will either be included in AFM 67-1, *USAF Supply Manual,* or a new armament (AFR 136-X) series directive.

Quality Assurance

Quality assurance guidance will soon be released to AFSC and AFLC which will define the use of quantifiable measures of quality for systems and spares acquisition, as required by AFR 74-1, *Quality Program*. This guidance supports top-level leadership efforts to have project/program managers collect and use quality assurance data on predetermined elements for development and production programs. This guidance will have a positive influence on the design and manufacture of weapon systems. By carefully selecting quantifiable measures of quality for systems being manufactured, government program managers can monitor and take steps to change processes before significant numbers of units have been manufactured which fail to meet systems specifications. The goal is to improve weapon system quality and to provide objective historical data which would be of use during source selection.

RIVET MILE

Programmed depot maintenance (PDM) has long been a way of life for aircraft maintenance, but we have never been able to fly our Minuteman silos to the depot. Beginning in April 1985, we will take the depot to the sites as OO-ALC begins a much needed PDM effort for the 1100 Minuteman launch facilities and launch control facilities. This program, known as RIVET MILE, was funded in the FY85 Program Objective Memorandum (POM). Planning by OO-ALC and SAC is well underway for this new approach to increase the service life of the aging, but still critically important, Minuteman System.

Airlift Surplus

Strategic airlift enhancements (C-5A wing modification; KC-10 and C-5B procurement), now underway, not only reduce wartime airlift shortfall, but also significantly increase the transportation by-product generated by peacetime flying hour training programs. The productive use of this valuable peacetime by-product presents new logistics challenges. A new, unfamiliar era of surplus airlift management is now emerging. Soon the regular peacetime airlift requirements of the military services will be insufficient to fully use the transportation by-product of airlift readiness training programs. Special policy and programs, recently approved, will be promoting greater use of this valuable by-product. In FY85 MAC cargo tariff rates have been restructured to align them more closely with those in the civil sector; and new incentive tariffs for morale related commodities such as household goods, seasonal exchange items, and perishable goods will be implemented.

Warranties

Public Law 98-212 (FY84 Defense Appropriations Act) requires the Department of Defense to obtain a written guarantee from the prime contractor or other contractors for a weapon system funded by this or any subsequent act. Should the system, after acceptance into the USAF inventory, fail to perform as contractually specified, the written guarantee obligates the contractor to bear the cost of all work to repair or replace such parts as necessary to achieve the government's performance requirements. If the contractor fails to accomplish such work promptly as determined by the Secretary of Defense, the contractor will pay the costs incurred by the United States in procuring such parts from another source. The Secretary of Defense may waive this statutory requirement provided he gives written notice of his intentions to the House and Senate Armed Services Committees and House and Senate Appropriations Committees. A waiver may be granted if obtaining the written guarantee would not be in the national interest or would not be cost-effective. The Secretary of Defense has waived the law on all applicable contracts being awarded through 14 March 1984. This waiver was granted so as not to delay the timely acquisition of defense material while guidance on complementing this law is developed.

FUTURE ISSUE

We plan to dedicate the Fall issue of the *Air Force Journal of Logistics* to the Future (ideas, concepts, and technologies). We will consider articles or items of interest which focus on this theme. Our last Future issue (Summer 1982) elicited many favorable comments because people are fascinated by the future. THE FUTURE IS LOGISTICS!

(Please submit your article to AFLMC/JL, Gunter AFS AL 36114, before 1 July 1984.)

Theft and Diversion from Aerial Ports and Supply Depots: An Internal Assault on the Integrity of Wartime Capabilities

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Abstract

In order for the Air Force to meet present and future mission requirements, it must have a logistics infrastructure capable of supporting operational units on a real-time basis. There are, however, both *internal* and *external* threats to the integrity of the logistics system.

External threats include inadequate funding, the nonavailability of needed resources, lengthy lead times in materiel acquisition, a diminishing industrial capacity, and a shrinking manpower pool. The internal threats include the problem of theft and diversion of supplies from the supply and transportation systems.

This paper will discuss the external and internal threats and present different approaches to the problem. One major area involves human resource approaches which can include more effective education, training, and assignment of Air Force personnel who work within the supply and transportation systems. A second major area involves physical resource protection techniques. More stringent controls over equipment, especially while it is in transit or in supply channels, may reduce the scope of the problem. Greater use of property marking is also seen as a valuable approach to the problem.

The importance of personnel and property management is an urgent responsibility of all Air Force commanders. They can make a significant impact by constantly applying countermeasures to protect USAF supplies and equipment.

External Threats

In order to meet its global mission throughout the remainder of the 1980s, the USAF must be prepared to carry out sustained operations under virtually any set of circumstances. This requirement will probably be complicated by such factors as rapidly changing political environments (especially in the lesser developed countries); increased economic interdependence among nations with differing social and demographic needs;[1] and the further evolution of transnational organizations, both political and corporate.

"*External threats to the system encompass those which lie outside the control of Air Force planners. . . .*"

Because it is impossible to predict the future operating environments of Air Force units, it is essential that the USAF maintain supply and transportation systems capable of supporting operations under very diverse circumstances. This means that a well-established logistics infrastructure must be in place during peacetime and that it must be capable of rapid expansion in wartime so critical supplies can be provided to users on a real-time basis. The requirements of the logistics system are well understood; however, there are a number of threats existing (internal and external) that challenge its integrity.

External threats to the system encompass those which lie outside the control of Air Force planners and which tend to diminish the ability of the system to sustain its clientele. Following are several key external threats to the integrity of the logistics system:

Inadequate Funding

Inadequate funding can preclude the sufficient acquisition of parts and the development of systems and technologies required to sustain operations. Since ours is essentially a zero-sum economic system (a dollar appropriated for one function does not go to any other function), there is of necessity great competition for money. Defense must compete with all other areas of government spending. Moreover, the budget system is in itself an extraordinarily complex and political process. It is common for Congress to compromise heavily on budget requests, producing what it believes to be a fair apportionment among those competing groups within our society. The outcome often can result in the underfunding of key military requirements.

Nonavailability of Resources

Even if funding is available, it is by no means certain that the resources required will actually be available. This has become abundantly clear in the case of energy resources and could also be the case with those strategic and critical materials which are essential to military and industrial requirements in time of a national emergency. These materials include tin, silver, cobalt, bauxite, manganese, tungsten, zinc, titanium, and platinum. The United States (US) must import many of these materials from countries which in turn face much political uncertainty. Moreover, the strategic and critical materials stockpile of these items is down in every category from the 1970 levels.[2]

Long Lead Time

Even where funding is adequate and the resources are available, there can be a lengthy lead time between the establishment of a requirement and the delivery of the finished product to its users. This process is variable and can take up to ten years, and it is clear that such lengthy delays can have a significant impact on the ability of Air Force units to meet mission requirements.

Diminished Industrial Capacity

This factor is obviously related directly to lead time, but it also serves as a member itself of the threat equation. This factor simply addresses the problem of industry being unable to produce certain goods or products. In a competitive and regulated industrial system, there is no assurance that certain

goods will even be manufactured during peacetime. Manufacturers naturally seek out more productive markets, and those items with limited military application may not compete with others for which larger and more profitable markets exist. In addition, increasingly more research and development money is being invested in fewer (but more expensive) long-duration development programs. This not only delays the application of modern technology to equipment currently in use but also ". . . cuts down military options and greatly reduces the chances for major technological innovations, especially those coming from the small, inventoried companies."[3] The results have been grim: "reduced force readiness and sustainability; declining industrial productivity and responsiveness; and greatly reduced quantities of military equipment - all badly needed for force build-up and modernization."[3]

The Shrinking Manpower Pool

The Air Force relies heavily on a throughput of young men and women to fill its ranks and to perform the vital jobs necessary to sustain operations. However, the US population is aging; its median age at present is 30 years.[4] Since the Air Force must compete for its human resources in an increasingly competitive marketplace, it must anticipate having to do as much or more as in the past, but with fewer people. This is illustrated by the fact that the number of active duty military personnel, in terms of ratio per 1000 total population, is at its lowest level since 1940.[5]

In addition, the increasing sophistication of military weapons and their support systems requires a work force capable of operating those systems. However, even though 68.6% of all Americans 25 years of age and older were high school graduates as of 1980, many of those who enter the military will lack some basic skills and will have to be given remedial training.[6]

These are but a few of the external factors which represent a potential threat to the integrity of the logistics system. Solutions to these problems should be a matter of concern at the highest policy levels, and planners must consider the stark fact that for some of these there may be *no* satisfactory solutions. However, perhaps even more critical to our logistics infrastructure are the internal threats to system integrity.

"If items do in fact enter the system but are lost because of theft or diversion, they represent a compound loss to the Air Force."

Internal Threats

The external threats to the integrity of the logistics infrastructure may be expected to result in three primary outcomes: (1) a shortage of replacement parts, (2) some inventory management problems, and (3) widely felt distribution shortfalls. As serious as these problems are, they can be severely exacerbated by *internal* threats to the supply and transportation systems. Two *key* threats are theft and diversion. If items do in fact enter the system but are lost because of theft or diversion, they represent a compound loss to the Air Force. Their original cost is thus increased by a replacement cost, their use may be denied to operational units which need them, and their loss may benefit hostile forces.

Theft: The Problem

The theft of government property is an expensive and continuing problem. From 1976 through 1981, the Air Force Office of Special Investigations (AFOSI) conducted an average of 795 investigations per year into major allegations of theft of government property. The average loss to the USAF during each year of this period was $1.8 million (against average annual recoveries of $860,000).[7] However, these figures should be interpreted with considerable caution as they do not include cases of theft of government property which were not investigated by AFOSI; furthermore, they do not include thefts through fraud, conversion, or illegal disposal. Thus the dollar value and the number of cases cited must be accepted as a very conservative estimate of the problem. In addition, the value of government property restored to USAF custody as a result of AFOSI recoveries can also be misleading. Property recovered in any given year may have been stolen during previous years, and some of the property recovered may never have been reported as stolen in the first place.

The kinds of government property stolen cover nearly the full range of items in the inventory; however, among the leading categories of theft are electronics equipment, aircraft equipment and parts, and tools. A substantial number of thefts take place in the supply warehouses and also while the goods are in transit.[8]

The seriousness of the problem was illustrated in a series of AFOSI investigative operations at an overseas base where undercover agents were targeted against the supply and transportation squadrons at a major facility. Two agents worked under cover for seven months (from March 1981 through September 1981). As a result, a major theft ring was identified and neutralized. The ring, composed mostly of locally hired USAF employees, operated a very sophisticated system which pinpointed desired items and removed them from the supply and transportation systems. Some of the losses were accomplished through outright theft, but many were supported by document manipulation using off-line computer terminals. Among the items most sought by the ring members were aircraft and electronics parts. It is estimated that the annual losses to the USAF as a result of the activities of this one sophisticated group ranged somewhere between $4 million and $6 million per year. In another instance, four intruders—one of whom was a former USAF employee—broke into a unit supply facility at an overseas base and stole approximately 45 of the 60 aircraft mechanics' tool kits and a substantial amount of parts and equipment. The thieves were intercepted by OSI agents and the property recovered. Had this action succeeded, a LINEBACKER II unit would have been grounded.

Theft: The Incentives

A number of important factors influence the kind and quantity of items stolen from supply and transportation channels. For one thing, there is a major market for replacement parts for American-made military equipment which is now in the hands of nations that do not have legitimate access to conventional sources of supply. The maintenance of this equipment (including aircraft) is important to these nations if they are to project political power in their respective spheres of influence. Replacement parts for this equipment are sought in an international marketplace, which results in a significant monetary incentive for the theft of these parts from USAF facilities. The problem is made all the more complex when the parts targeted for theft are situated in

sometimes vulnerable overseas bases and where many of the employees at those bases are local hires who have access to international arms markets.

> "Thus the ready availability of lucrative markets for stolen USAF items constitutes a strong incentive for individuals who have relatively easy access to them."

A second factor is that much of the property stolen from the USAF has potential application in nonmilitary settings (medical and dental equipment, communications equipment, and construction equipment). The demand for these items will probably be quite high at overseas locations where the local economy can be characterized as "developing" and where this kind of high-cost equipment must be imported. This condition is aggravated in countries where import taxes are high and where local businesses face large problems in basic capital formation. Thus the ready availability of lucrative markets for stolen USAF items constitutes a strong incentive for individuals who have relatively easy access to them.

A third factor is that many USAF items cannot be easily identified as government property. Therefore, once removed from their proper channels, it may be difficult to recover them through judicial or law enforcement processes. This retrieval is often complicated by the procedural or evidentiary requirements of host nation laws or our own treaty obligations.

Diversion: The Problem

In the case of theft, government property is taken with the intent to permanently deprive the government of its use or benefit. In the case of diversion, the property may ultimately be returned to the custody and use of the government; however, during the period of its misuse, it is lost to the Air Force. In that sense, it is "temporarily stolen" without any benefit to the government. In other cases, the property may be diverted for government use, commonly called "scrounging"—a practice which may have short-range benefits but which can lead to long-term disadvantage. In 1981, AFOSI conducted 151 investigations of the improper use or diversion of government property or government employees. In the bulk of these cases (78%), government property was misused for the personal benefit of the person doing the diverting.[9]

> "Thus, there may be a multiplier effect in acts of theft and diversion which accelerates the rate of system dysfunction."

Theft and Diversion: Consequences

(1) Although the theft or diversion of government property during peacetime may not seem to diminish the ability of the Air Force to conduct wartime operations, appearances can be misleading. In reality, theft and diversion can significantly impair the *potential* ability of the Air Force to conduct wartime operations.

(2) The loss of certain items may have a consequence totally out of proportion to the dollar value of the item taken. Even though operational aircraft may be on the line and adequately fueled and armed, the absence of crew clothing, environmental or avionics equipment, or minor items such as a mechanic's tool kit can result in reduced sortie rates and a drop in overall operational effectiveness.

(3) The loss of aircraft parts not only removes critically needed items from the replacement inventory, but those same items in the hands of hostile powers may enhance their offensive or defensive capabilities to the clear detriment of US interests.

(4) The replacement of stolen or diverted equipment multiplies its acquisition cost (aggravating the funding problem referred to earlier), as well as resulting in significant opportunity cost in terms of missions not flown or operations aborted. In addition, the replacement of stolen or diverted parts or equipment adds to the lead time for acquisition. This last point is especially important, as timeliness may well be one of the key ingredients to success in future military operations.

(5) The absence of parts or equipment may itself produce an incentive to divert, or "scrounge." This produces a problem analogous to the parking lot dilemma: when someone parks in another person's assigned slot, it forces everyone else to do the same thing. Thus, there may be a multiplier effect in acts of theft and diversion which accelerates the rate of system dysfunction.

In summary, if USAF combat elements are to maintain high sortie rates under conditions of sustained combat, it is essential that a well-established logistics infrastructure exist and that it be capable of providing critically needed supplies to users as they are required. The theft or diversion of supplies can seriously diminish the viability of an operational unit, especially if replacement stocks are low, involve long lead time, or are otherwise in short supply. Thus, it is important that the problem of theft and diversion be considered as a serious limiting factor when assessing wartime capabilities.

The Synergistic Threat

External and internal threats to the integrity of the logistics system combine to form a synergistic threat—a new threat which is greater than the sum of its parts. One result of this phenomenon is that individual components of the problem exacerbate other components, producing a multiplier effect. For example, reduced fiscal allocations for military spending result in the acquisition of fewer (and more expensive) items, reducing then the resupply inventory. These items enter a supply system which is staffed by increasingly fewer people who tend to be in lower pay grades and who also are relatively inexperienced. In order to locate these supplies where they will be most needed, some of them have to be prepositioned in overseas areas. In many cases, the movement and storage of these goods will be physically controlled by local nationals who may have a different cultural perspective on theft and corruption and who may live in areas in which there exists a lively illicit market for goods stolen from the Air Force.

Thus, *a structure of vulnerability* emerges which is easy to underestimate because it is seldom seen in full perspective. Moreover, most components of the problem involve issues that are dealt with by different parts of the total system. Unfortunately, those components tend to act in relative isolation from one another which results in many of these problems not receiving the kind of networking necessary to significantly reduce their impact.

This same "interaction effect" produces yet additional threats. For instance, the need to direct a complex array of parts and equipment to diverse places, using limited manpower

resources, calls for a greater reliance on automated data systems. These systems are fast and efficient; however, they are also subject to manipulation—a fact discovered in numerous AFOSI investigations. The extensive use of data processing enables fewer thieves to do far more damage with much less risk of getting caught.

Another issue involved is the status within the items themselves. The overwhelming majority of these items exist in a kind of "No Man's Land," since they are not already in use nor are they in the hands of their end users. They represent, for the most part, "bulk" and are thought of in terms of their volume, weight, and the shipping documents which accompany them while in transit. Moreover, their transient status makes their accountability all the more difficult. In fact, accountability becomes a function of the management of the shipping documents, often leading to a kind of sophisticated "shell game." In the supply and transportation systems, the documentation used to control the property is the "shell," and the property is the "pea." However, in the logistics game, there is supposed to be a pea under every shell. In practice, this does not always prove to be the case and therein lies the danger. All too often peas are accounted for by counting shells rather than by counting peas.

Finally, the complexity of the system and the sheer number of items involved in transit mean that it is impractical to expend a great deal of time or effort in trying to trace "a few" missing items—even if those items as individual units are very expensive. The result is that the audit trail may be checked, sometimes up to three times per item; but if the missing item is not located, it is simply reordered. This represents a kind of reverse economy of scale in which the value of individual items is dwarfed by the magnitude of transactions which surrounds them.

Approaches to the Problem

The theft or diversion of government property does reduce the wartime operational capabilities of the Air Force, even though the actual quantity of items involved may be small or the number of violators few. What measures can Air Force officials take to reduce the scope of the problem and to minimize the impact?

> *"... it should also be pointed out that prevention is more important than punishment."*

From the outset it should be clear that all military members must be held fully accountable for their actions. Theft and diversion are serious matters and military members should not be allowed to think otherwise. Swift, sure punishment for these crimes carries a potent message to others, and the deterrent value of this type punishment should not be overlooked. Having said this, it should also be pointed out that prevention is more important than punishment. From a purely practical perspective, prevention is more pragmatic than punishment, especially since the threat of punishment may be of little value in dealing with foreign nationals who may not in fact be subject to US law and procedure. Approaches to the prevention of theft and diversion seem to fall into two broad categories, each of which offers a number of possible solutions. Those two categories may be described as "human resource approaches" and "physical resource approaches."

Human Resource Approaches

When government property is stolen or diverted by people, specific individuals are in turn responsible for these acts. This being the case, the management of human resources presents a potentially powerful key to the protection of USAF assets. What are some of the countermeasures that can be taken, through and with people?

The first step is educational: Air Force members involved in the transportation and storage of government property must be made fully aware of the significance of their responsibilities. They need to know that the items in their custody represent far more than tax dollars spent on defense materials and that those same materials represent the ability of the Air Force to conduct and sustain future operations. They also need to know that the intentional theft or diversion of those materials may very well be comparable in seriousness to acts of sabotage.

Second, these key personnel must be properly trained, assigned, and managed. People who are unhappy with their jobs are less likely to be motivated by principles of responsible stewardship. In fact, one is far more likely to encounter passive or even active aggression among unhappy workers, and this can translate into indifference or hostility towards the job—with predictable results.[10] Using too few people to do the job properly or staffing positions with incumbents who fall below minimal levels of experience and training can also be an invitation to trouble. Organizational manning below established manpower standards results in less than desirable supervision and an experience level in management that detracts from the ability to identify loss trends. In addition, it should be remembered that continued taskings from higher headquarters without a corresponding increase in manpower can spread management surveillance too thin and make it easier for theft rings to operate. Finally, caring about one's subordinates—a vital component of leadership—is critical.[11] It is far easier to manage from a nice, comfortable, air-conditioned office than to visit with the people who work in the warehouses. It is also seductively easy to take a subordinate's word that "everything is OK" without actual on-the-spot verification.[12] Also, there is little incentive for lower ranking enlisted members to be honest when they perceive senior NCOs as well as commissioned officers being less than honest. The basic principles of effective and efficient management have been well understood for years and have been carefully articulated in everything from management texts to professional military education programs. We must as Air Force leaders follow those principles.

Third, responsible Air Force officials in the supply and transportation systems can take better advantage of existing resource protection technologies. For example, officials in AFOSI can assist in the development of positive intelligence to identify the kinds of Air Force property most sought after in local illicit markets. AFOSI has conducted highly successful undercover operations in which agents have been placed within supply and transportation systems, resulting in the interdiction of major theft rings. Commanders who have reason to suspect they have a serious problem can request similar assistance from AFOSI. If commanders are not sure they have a problem, they can request AFOSI assistance in surveying operations to see if a problem does in fact exist. Finally, supply and transportation officials should consider the development of techniques for "integrity testing" as a quality assurance device for the protection of their resources. Airmen who are so tested and who demonstrate their integrity should be properly rewarded.

Fourth, in overseas operations in which supply and transportation systems use large numbers (or proportions) of local hires, great care must be exercised in the degree of freedom given to these individuals. This is not intended to disparage foreign employees, many of whom have provided long and honest service to the Air Force, but we do recognize that there is a very genuine problem. People in many overseas locations live under constraints and pressures quite different from those faced by Americans. The exploitation of American resources by foreign workers, former employees, and intruders has been well-documented in many investigative case files. Foreign national employees should be "buffered" by US military personnel. They should not be placed in positions where they can "network"; that is, where they have parallel contact with one another and can thereby bypass security or management controls. For example, where supply areas or compounds are guarded, the guards should not be local hires if they are used to transport goods out of those compounds. Finally, experience has shown that some positions within supply and transportation lend themselves to illegal activities when manned by the same person over a long period of time.

Physical Resource Approaches

The other side of the human resources approach involves the management of physical resources. Perhaps the potentially most important area of prospective improvement in safeguarding Air Force property lies in the development of a system which marks that property. A great deal of the property owned by the government has nonmilitary application and may be indistinguishable in appearance from civilian property. It is vital that government property be identified as such by some means or another; the failure to do so merely facilitates its theft or diversion and mitigates against its successful recovery. How this is to be done is no doubt a difficult and complex issue; however, the marking of government property should be a matter of major concern to senior Air Force officials.[13]

Second, more stringent controls should be placed over cargo in transit. Investigative case files have clearly shown that it is quite easy to "frustrate" cargo and then prepare false documentation so it can be diverted and subsequently stolen. Also, the placement of stock classes on cargo which identifies contents also flags that property for individuals looking for specific classes of cargo to pilfer. "Quick Release" procedures, designed to facilitate the fast delivery of supply items, are also susceptible to exploitation and should be carefully examined and restricted to mission-essential items.

Investigations have also shown that not all facilities enforce adequate physical security to preclude unauthorized entry into supply areas. Controlled area procedures should be developed and a system of passes instituted and enforced. Basic physical security, properly conceived and effectively administered, is a very powerful means of preventing loss. Security specialists in the Security Police career field can provide Air Force commanders with assistance in this area.

In summary, the reduction of theft and diversion calls for an active and open approach to the problem. Weaknesses must be identified and appropriate countermeasures instituted. The countermeasures must focus on those human and physical resource areas most susceptible to exploitation. The elimination or reduction of theft and diversion from supply and transportation systems should be viewed as a potent force multiplier and key to greater effectiveness.

Conclusions

Although the most apparent problems in logistics usually involve the acquisition of military hardware, it is clear that the delivery of those same materials is of no less importance. Even where the materials are acquired and delivered to the locations where they will ultimately be used, the integrity of the logistics system remains in jeopardy if those items are subject to theft or diversion.

There is little that Air Force planners can do to prevent the external threats to the logistics system; they are, by their very nature, beyond the control of Air Force officials. The military, as a microcosm of the larger society, will remain subject to those same economic, social, and political pressures which influence virtually all segments of the national economy.

However, the Air Force is in a position to deal with the internal threats to the integrity of the logistics system. Unfortunately, one of the greatest dangers of the internal problems is that they are seldom seen in their full, synergistic context. For this reason many officials tend to underestimate the magnitude of the threat which they pose. Moreover, the attempt to deal with problems by addressing their symptoms rather than their causes is a common failing in our society as a whole.

The theft or diversion of government property can seriously limit the ability of Air Force units to carry out their missions. In fact, the problem of theft and diversion should be viewed from the perspective of force limiters rather than just as criminal acts. From this perspective, the importance of personnel and property management becomes a more urgent responsibility of all Air Force commanders, especially those within the supply and transportation systems.

The application of carefully reasoned countermeasures to protect USAF supplies and equipment is a subtle but significant force multiplier that can, in the final analysis, tip the scales in favor of the US in a military conflict.

Notes

[1]Calleo, David P. *The Imperious Economy* (Cambridge: Harvard University Press, 1982) and Hunter Lewis and Donald Allison, *The Real World War: The Coming Battle for the New Global Economy and Why We are in Danger of Losing* (New York: Coward, McCann & Geoghean, 1982).

[2]U.S. Department of Commerce, Bureau of the Census. *Statistical Abstract of the United States, 1981* (102nd edition), Washington, D.C., 1981. See Table 1312, "Federal Strategic and Critical Materials Inventory: 1970 to 1980," p.731.

[3]Gansler, Jacques S. "Can the Defense Industry Respond to the Reagan Initiatives?" *International Security* (Spring 1982): 102-121, reprint ed., *Current News* (Special Edition), 886 (29 July 1982), p. 2.

[4]*Statistical Abstract, 1981*, Table 26, "Population by Sex, Race, Residence, and Median Age: 1790 to 1980," p. 25.

[5]Ibid., Table 597, "Department of Defense - Active Duty Military Personnel: 1940 to 1980," p. 362.

[6]Ibid., Table 229, "Years of School Completed, by Age and Race: 1940 to 1980," p. 141.

[7]U.S. Department of the Air Force, Air Force Office of Special Investigations. *Investigative Activity Report* (for calendar years 1976 through 1981). FOUO.

[8]Based on information contained within the AFOSI Investigative Data Base, which consists of closed case files. Data within those files are cumulated through a computerized case survey system.

[9]*Investigative Activity Report*, 1981, p. A26.

[10]Lewin, Kurt, Ronald Lippitt, and Ralph K. White. "Patterns of Aggressive Behavior in Experimentally Created 'Social Climates,' " *Journal of Social Psychology* 10 (1939); Frederick Herzberg, "One More Time: How Do You Motivate Employees?" *Harvard Business Review* 46 (January-February 1968): 53-62; and Milton R. Blood and Charles R. Hulin, "Alienation Environmental Characteristics and Worker Responses," *Journal of Applied Psychology* 51 (June 1967): pp. 284-290.

[11]Likert, Rensis. *New Patterns of Management* (New York: McGraw-Hill, Inc., 1961), Chapter 11, "The Nature of Highly Effective Groups," and Robert Tannenbaum and Warren H. Schmidt, "How to Choose a Leadership Pattern," *Harvard Business Review* (March-April 1958): pp. 95-101.

[12]For an excellent discussion of this problem, see Downs, Anthony, *Inside Bureaucracy* (Boston-Little, Brown and Co., 1967), particularly Chapter 12, "Control Process and Devices," pp. 144-157.

[13]Property marking may involve some vexing questions of cost-effectiveness. For example, the cost of marking property may in some cases exceed the value of the property. However, the loss of that same property, if unmarked, could exceed its value if it *was* marked.

New Fuels on the Horizon

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Abstract

Over the next 20 years, the Air Force will require increasing amounts of energy to accomplish its mission. To meet these increased requirements and reduce our dependence on foreign oil, new fuel types are being developed that could be used by the Air Force to improve sustainability in an energy emergency or supply disruption. There are several alternative fuels that might be considered for Air Force use derived from something other than petroleum, such as synthetic fuels from oil shale, coal, or tar sands; liquid hydrogen; and liquid methane. This paper addresses the feasibility of developing and using these alternative fuels in flight and ground operations applications, with the conclusion that not all of these resources will provide equally attractive fuels. An exception is JP-4 derived from oil shale—an alternative fuel which the Air Force is developing for use in the near future.

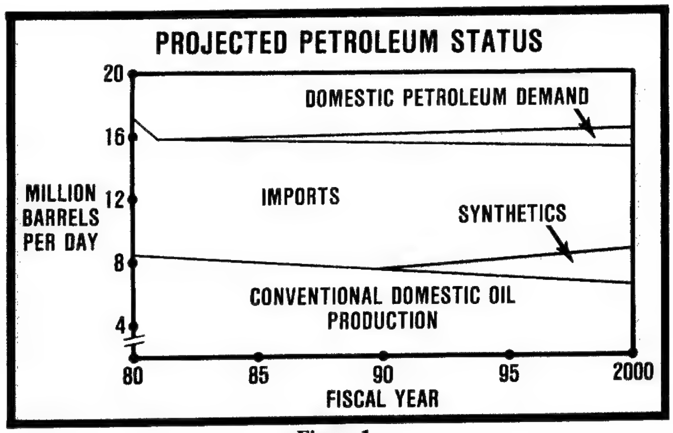

Figure 1.

Introduction

The Air Force relies heavily upon petroleum products in carrying out its mission. In the past oil shortages have occurred in 1973 and 1978, highlighting the vulnerabilities of both the United States (US) and the Air Force (AF) to imported oil. Past administrations have taken extensive actions to reduce oil imports and develop alternate energy sources. Executive Orders, for example, limited the net imports of crude oil and refined products, outlined energy reduction goals for federal agencies, and established incentives to develop alternate energy sources. The composite price of crude oil climbed from $10.89 per barrel in 1976 to about $33.95 per barrel in 1982 primarily due to domestic oil decontrol and escalating oil import prices.[1] Past government activities and price increases have accelerated alternate fuel development in the US. The present administration, however, believes that the free market, not the government, should lead in developing energy initiatives.[2] Investors now have a diminished interest in developing alternate fuels due to relatively stable oil prices and the high technology risk associated with synthetic fuel plants. These recent developments will tend to delay availability of alternate fuels and continue the US dependence on imported oil.[3]

Petroleum products supplied for domestic use in 1983 averaged 15.0 million barrels per day, down 20% from a high of 18.8 million barrels per day in 1978.[4] This decline in energy consumption is considered to be a result of energy conservation, fundamental changes in energy consumption patterns, and reduced economic activity. Total domestic field production of conventional oil and natural gas liquids averaged 10 million barrels per day and is projected by the Department of Energy (DOE) to steadily decline to about 6 million barrels per day by the year 2000[5] (Figure 1). In spite of reduced domestic oil production, there is currently sufficient crude oil to meet domestic energy demand and this availability is considered an "oil glut." Although crude oil is readily available, current domestic oil stocks are at a low level because of reduced energy demand, the practice of drawing on existing inventories during a period of dropping oil prices, and the high cost of money to maintain inventories. For example, in June 1983, domestic stocks of diesel fuels and fuel oils were at 112 million barrels which is below the minimum operating level of 125 million barrels established by industry. This is caused by the conditions previously mentioned, plus the fact that refiners have been unable to increase the ratio of diesel production to gasoline production and the lower quality of crudes makes diesels more difficult and costly to produce.[6] Although petroleum demand is down in recent years, it is projected to increase. Domestic air traffic as well as the

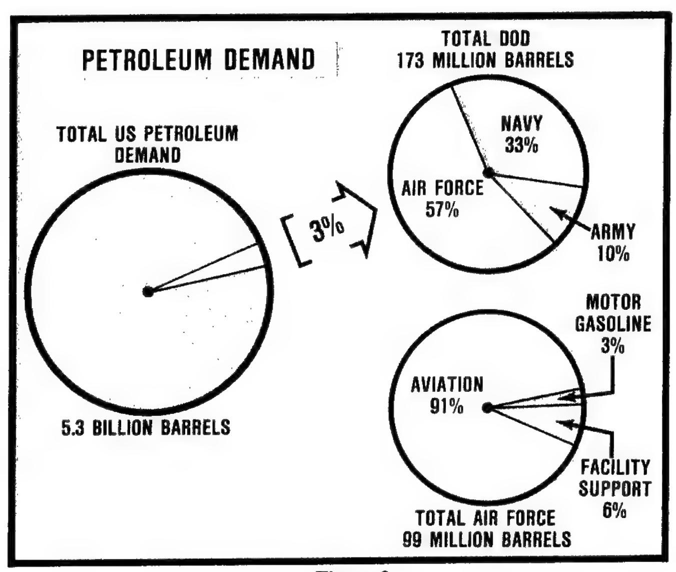

Figure 2.

demand for jet fuel is projected to increase through 1995. Currently, domestic jet fuel represents 5.2% of the total refining output and may increase to 8%. Refiners must be able to find a reasonably secure market for the entire spectrum of petroleum products which will keep demand up for middle distillate fuels such as jet and diesel fuels.[7] The Department of Defense (DOD) energy consumption at present is approximately 474 thousand barrels per day (Figure 2). Air Force fuel requirements average 271 thousand barrels per day and are projected to increase about 2% a year (Figure 3).

The benchmark for crude oil established by the Organization of Petroleum Exporting Countries is $29 per barrel, and many energy experts forecast that oil prices will remain fairly stable until 1990. The price of oil should stay behind inflation but increase as demand changes. A rapid increase in oil prices could damage any economic recovery, while a major reduction in oil prices could adversely affect both producers and consumers.[8]

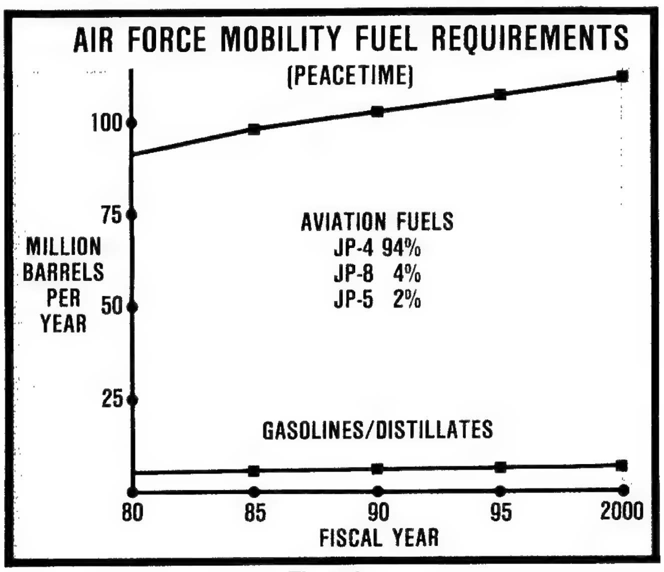

Figure 3.

Fuel Use Development in the Air Force

At the present time, the primary AF fuel is JP-4 which accounts for 93% of total USAF aviation fuel use. JP-4 is a naphtha-based fuel with a relative high vapor pressure. Over the past decade, there has been an increased advocacy for the use of JP-8 fuel as a replacement for JP-4. The original push to convert from JP-4 to JP-8 fuel was for safety reasons and the fact that JP-4 competes with domestic motor fuel requirements. JP-8 is a kerosene-based fuel (similar to commercial Jet A-1) with a low vapor pressure and a minimum flash point of 100°F. The Air Force has converted completely to JP-8 fuel at its bases in the United Kingdom as a North Atlantic Treaty Organization (NATO) initiative for interoperability and safety. NATO has agreed to start conversion to JP-8 on the European continent by 1 Jan 1987. There are no plans, however, to convert the CONUS to JP-8 fuel because of the high cost to the domestic refining industry in converting to kerosene-based fuels for the military and the potential major disruption a conversion would create for the domestic commercial airline industry.

The development of a completely new propulsion concept takes 25 to 50 years from the time of basic research to operational use. This means that the type engines in use today are expected to be using basically the same fuel type beyond the year 2000. Engines entering the inventory, such as the CFM-56 to be used on the KC-135s, over the next few years will further extend AF reliance on jet fuels. Retrofitting existing aircraft with new technology engines is not an attractive concept due to the age of the aircraft itself, the high cost of engine procurement, and relatively long paybacks based on fuel savings. Therefore, the evolution of jet fuels or the development of new fuels in the near term must be compatible with existing engines and aircraft.[9]

The Air Force has developed a systematic approach to assure the continued availability of aviation jet fuels. The Air Force Systems Command (AFSC) Aviation Turbine Fuel Technology (ATFT) program has three main objectives:

(1) Allow feedstocks other than petroleum to be used to produce the fuels.

(2) Change fuel specifications to not only allow for new feedstocks but to optimize commercial availability.

(3) To make hardware design changes in current or future systems to allow use of new specification fuels.

An additional benefit is the potential to reduce production costs of future aviation jet fuels by optimizing the fuel specifications for commercial availability. The program's near-term objective is to try to use lower quality crude oils and shale oils without requiring hardware and major specification changes. In the longer term, hardware design changes will be required if feedstocks and fuel specifications change.

There have been recent changes in commercial fuel specifications because of changes in feedstocks and attempts to increase the availability of middle distillate fuels. For example, the Jet A-1 fuel specification was relaxed from a freeze point of −50°C to −40°C in an effort to reduce fuel costs and increase the yield of aviation products from a barrel of crude. Mission degradation is not expected, although the Air Force Logistics Command (AFLC) is continuing to study effects of this specification change. The AF made an effort to reduce the vapor pressure of JP-4 for environmental and safety considerations, but it was never implemented because industry was not able to adequately support the initiative. The overall result is that the AF energy requirements will continue to evolve based on available fuel types and the ability of existing AF aircraft to effectively burn these fuels. This evolution will continue to rely on the availability of crude oils to produce middle distillate fuels.

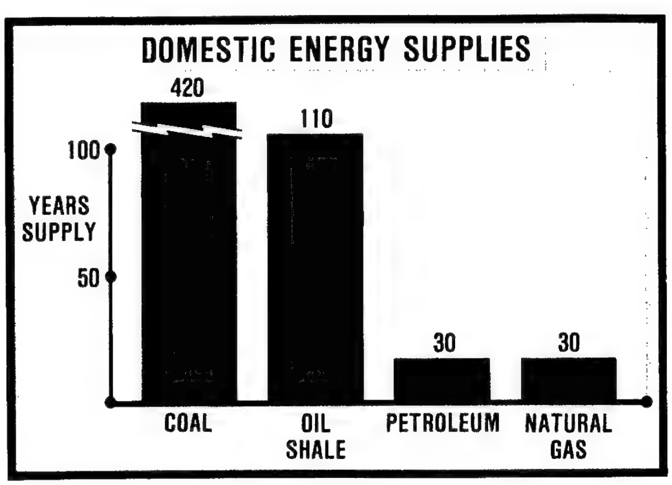

Figure 4.

Synthetic Sources of Petroleum

The use of synthetic crudes as a petroleum feedstock will allow evolutionary development of new energy resources of the future. Synthetic sources of crude generally include oil shale, tar sands, coal liquids, and biomass. The total potentially recoverable energy reserves vary greatly depending on the assumed level of technology and the economics of recovering the energy. Estimates of US energy resources are shown in Table 1 (also see Figure 4).

Type Resource	*Quadrillion[10] BTU*
Coal	13,300
Natural Gas	775-1,030
Petroleum	800-1,100
Oil Shale	1,200-5,800
Uranium	1,800
Domestic Energy Consumption 1983	70

Table 1.

There are sufficient domestic energy sources to sustain the economy for a long time to come, but the basic problem is to develop the technology to take advantage of these sources. Investment in development of these energy sources has receded in recent years due to escalated costs of some processes caused by inflation and high interest rates. Money generally is not available for investment in projects that may not yield a profit in the near term. The temporary "oil glut" has also created a feeling that alternate energy sources may not be really necessary.[11]

A synfuels project must first be technologically feasible and environmentally sufficient to compete for investment funds; however, these funds are subject to long payback periods, economics of marketing the product compared to conventional materials, political risks both domestically and internationally, and interest charges.[12]

The status of major oil shale projects in the US will highlight some of the problem areas in developing shale oil. The Union Oil Project at Parachute Creek had a production goal of 10,000 barrels per day by the end of 1983 with a potential to expand from 100,000 to 150,000 barrels per day in later years. The significance of the Union project to the Air Force is that DOD has first refusal rights to all products produced under terms of a DOE/Union Oil purchase agreement. Union has been involved with shale oil development since before the 1950s. Construction of the Parachute project started in 1980, was essentially completed by September 1983, and should begin production in early 1984. The Union project is a conventional room and pillar mine, and the raw shale will be placed in an upflow retort which is expected to provide a premium syncrude feedstock. The joint Colony project by Exxon and Tosco was projected to produce 47,000 barrels per day by 1985. This project, which was designed around US government financial incentives ($1.1 billion loan guarantee), was to have provided 10,000 barrels per day of shale-derived fuels for DOD use. However, the project was canceled when Exxon withdrew in May 1982, buying out Tosco's interest. Exxon cited huge cost overruns, more optimistic assessments on crude oil availability, and lower crude oil prices as reasons for dropping the project. Oxydental Oil Shale, Inc., has received a $2.189 billion letter of intent for development of their *in situ* oil shale process on the tract c-b in the Piceance Creek Basin in Colorado. There are several other projects in various stages of design, engineering study, process study, or environmental hold that could be developed to produce syncrudes by 1990.[13] For example, one concept involves development of the Naval Oil Shale Reserves (NOSR) located in Colorado. Synthetic oil production levels between 10,000 and 200,000 barrels per day are technically feasible from this government-owned resource.

The major part of oil shale is kerogen, a high molecular weight material with about 6% oxygen and significant quantities of sulfur and nitrogen. Arsenic is often also present and must be removed. Hydrogen must be added to the shale oil to obtain synthetic crude oil for processing. Shale oil does, however, have a more favorable carbon-hydrogen ratio than liquids made from coal. Adding hydrogen in the presence of a catalyst, moderate pressure and high temperature also reduces the arsenic concentration. The shale oil then is generally hydroprocessed to reduce the density; remove sulfur, nitrogen, oxygen, and arsenic; and reduce the pour point and viscosity creating a quality syncrude. The syncrude can now be distilled into finished petroleum products. Depending on the severity of the hydroprocessing, JP-4 yields in the range of 34% to 90% from the base stock of syncrude are obtained with the remainder being a diesel blending stock, naphtha, and gas oils. The JP-4 made from syncrudes does meet the present conventional JP-4 specification in all respects. This JP-4 is made by different processes than conventional JP-4 and must be verified for use in high performance AF aircraft. For example, nitrogen content is not a specification item for JP-4; however, syncrudes may produce JP-4 with a nitrogen content. Hydrogen content is also a critical fuel property in aviation turbine engines affecting smoke emissions, combustion liner temperature (durability), and emissions of oxides of nitrogen.[14] The ATFT program effort which will validate aviation turbine fuel specifications for fuels derived from shale oil was completed in 1983. The second phase is an operational validation program which will start this year and use production shale JP-4 at two selected tactical AF bases. The ATFT program will then shift emphasis and consider coal liquids and tar sands as sources of syncrudes. Changes to the fuel specification limits will be a primary concern; however, data will be gathered for the long-term program to influence the design of future propulsion and fuels subsystems.

Coal can also be considered as a source for petroleum products. There are adequate coal resources in the US; the primary problem is to convert coal to a clean, usable product. In the past, coal conversion projects did not always involve a proper choice of conversion technology for the coal quality involved. A coal conversion project must be developed after a detailed integrated analysis of coal characteristics, market requirements, and technological capabilities. Coal gasification and indirect liquefaction are closer to being commercially economic than the direct liquefaction process. Two coal conversion projects are still proceeding in the US—the Great Plains lignite-based project to make synthetic natural gas and the Tennessee Eastman project to convert coal to methanol. Coal-based synthetic fuels production has been projected as high as 300,000 barrels of oil equivalent per day by 1990 and 2,000,000 barrels per day by the year 2000.[15]

Biomass is an additional source of petroleum products. The use of gasohol (10% ethanol, 90% unleaded gasoline) was popular in the past and was at one time generally thought to be

a major potential fuel source for the automotive industry. DOE estimates that biomass does have the potential of supplying 100,000 barrels per day by 1990. The technology to develop biomass is more available than that of shale oils in the near future. The use of ethanol as a motor fuel additive suffers from a limited domestic source for producing ethanol and the high cost of producing the required dry ethanol. Methanol production does not suffer from the same problems as ethanol and has a fairly large source of raw feedstocks and can be produced at a competitive price (about 80 cents per gallon). Methanol does present technical problems in compatibility with existing automotive engines and fuel systems. As the technological problems are evaluated and resolved, more interest is expected in methanol as a motor fuel. Alcohols have also been proposed for use in commercial and military aircraft. Even if all technical problems could be resolved, the aircraft would still have a definite restriction imposed on range due to the low energy content of the fuel compared to the weight and volume of aviation fuels.

Nonpetroleum Energy Sources

Nonpetroleum sources of energy include solar, geothermal, nuclear, wind, refuse-derived fuel, cryogenic fuels, and alternate vehicle fuels. These energy sources are generally considered only for application in ground power systems and facilities. The development of some of these energy sources is already well underway and in some cases provides a significant quantity of energy for the US.

The AF is actively involved in various solar energy programs to assess solar applications that are both technically and economically feasible. These projects include solar thermal systems and solar photovoltaics. Only active and passive solar thermal systems for space heating and water heating offer a realistic potential at this time. At the end of FY82, 35 solar thermal systems were operational and 10 were being constructed for a total cost of $9.5 million. Funding for the solar projects involves the Army/Air Force Exchange Service Program, which shares joint funding with the Department of Energy and the Military Construction Program. The AF is evaluating about 30 solar thermal projects for new facilities.

Geothermal energy can be obtained from hydrothermal, hot dry rock, volcanic, or geopressured sources. There are still some technical problems to be resolved; however, hydrothermal resources are the closest to commercialization. A water temperature up to 180°F can be used for water heating and space heating. A range of 180°F to 410°F absorption cooling and electrical production (via organic Rankine technology) is feasible. Above 410°F electricity can be produced by steam turbines. A survey was conducted in January 1982 and indicated a geothermal potential at Williams, Mt Home, Norton, Luke, and Ellsworth AFBs, and Saylor Creek Range. Geothermal energy can be developed according to Public Law 95-356, Title VIII, which allows energy contracts up to 30 years with civilian firms for construction and operation of a geothermal energy plant. Civilian avenues appear to be the best method for developing geothermal energy due to the high economic risk involved. Lackland AFB has a geothermal energy source at 136°F and could provide domestic hot water and space heating. A project to develop this resource would have a seven-year payback.

In 1983 nuclear power plants in the US produced approximately 282,773 million net kilowatt hours which accounts for about 13% of the total domestic electricity generated. This is up from the 83,479 million net kilowatt hours which accounted for 4.5% of the domestic electricity generated in 1973. Although nuclear power production is projected to gradually increase in the US, there are no specific programs to obtain nuclear power on AF bases. As part of the facilities research and development program, isotope use is being explored for applications such as runway lighting.

The Air Force is the lead service for wind energy and has established a program to locate economical wind sites. Wind energy is becoming commercially competitive since industry has solved many of the mechanical and electrical problems. Wind systems are considered only where economically feasible—an area should have both good wind potential and high utility rates. Two 25-kilowatt wind machines have been installed at Reese AFB and have been operating in a satisfactory manner since January 1982.

Another promising area is converting solid waste to a fuel to meet facility energy needs. Refuse-derived fuel is currently being tested at Wright-Patterson AFB. Existing boilers are being used and the annual consumption is 2,500 tons. The design of new coal plants considers the burning of these new fuels. The main problems in burning refuse-derived fuel focus around technical uncertainties, environmental concerns, and the cost and availability of the fuels.[16]

The Future

The US will be dependent on imported oil well beyond the year 2000. Only syncrude derived from shale oil or coal oil liquids offer any near-term relief from imported oil. The development of shale oil has progressed considerably from the 1970s. Current domestic development has receded and will result in lower available production in the next 10 to 20 years. However, the AF is rapidly developing the capability to use shale oil-derived JP-4 and expects to be ready to validate the use of this fuel as soon as it is commercially available. Further development of the shale oil industry will be dependent on the technology advances and the economics of energy sources.

Notes

[1]*Monthly Energy Review*, DOE/EIA-0035(82/08) (U.S.Department of Energy, Energy Information Administration, August 1983), p. 80.

[2]Memorandum, Deputy Secretary of Defense, to Secretaries of the Military Departments, Energy Conservation, 16 March 1982.

[3]Rahmer, B.A., "Successes and Setbacks for Alternatives," *Petroleum Economist*, June 1982, p. 241.

[4]*Monthly Energy Review*, DOE/EIA-0035(82/08) (U.S. Department of Energy, Energy Information Administration, August 1983), p. 15.

[5]*Energy Projections to the Year 2000*, DOE/PE-0029 (U.S. Department of Energy, Office of Policy, Planning and Analysis, July 1981), pp.5-6.

[6]Niering, Frank E., Jr. "Energy Development in Doubt," *Petroleum Economist*, May 1982, p. 177.

[7]Momenthy, Albert M. "U.S. Aviation Fuels Outlook" (Research Report for Boeing Commercial Airplane Company, May 1981), p. 1.

[8]*Energy Users Report*, Volume 10, Number 38 (The Bureau of National Affairs, Inc., September 1982), p. 969.

[9]Gebman, J.R. "The Potential Role of Technological Modifications and Alternative Fuels in Alleviating Air Force Energy Problems" (Rand Report R-1829-PR, Santa Monica, December 1976), p. 33.

[10]Hull, E.W. Seabrook. "Energy," *Journal of the American Defense Preparedness Association*, 31 August 1978, p. 3-F.

[11]Rahmer. *Petroleum Economist*, p. 247.

[12]Habit, J. "Financing Synfuels Plants," *Hydrocarbon Processing*, March 1982, p. 177.

[13]Williams, Bob. "Synthetic Fuels," *Oil and Gas Journal*, 28 June 1982, p. 71.

[14]Lander, Herbert R., Jr. "Jet Fuel from Shale Oil—1981 Technology Review" (Air Force Wright Aeronautical Laboratories symposium proceedings, AFWAL-TR-81-2135, December 1981) p. 1.

[15]Dickenson, R.L. "Write no Premature Obituary for Synthetic Fuels," *Oil and Gas Journal*, 28 June 1982, p. 104.

[16]*Air Force Energy Plan* (Washington, DC: Department of the Air Force, Oct 1982), p. 53.

CAREER AND PERSONNEL INFORMATION

Civilian Career Management

Logistics Civilian Career Enhancement Program (LCCEP)

LCCEP is now introducing some valuable new dimensions to basic interview techniques. The following observations relate to the importance of perfecting your interview talents so that LCCEP can work for you.

Since LCCEP is an Air Force-wide program with registrants who compete for jobs all over the world, it is not unusual for eight of ten candidates referred on a promotion certificate to represent different geographical areas. The Office of Civilian Personnel Operations (OCPO) provides a career brief for each candidate certified for consideration; however, if the selecting supervisor opts to hold interviews, he usually conducts them by telephone. This presents a double dilemma for the interviewer and the interviewee. In many cases, the parties do not know each other; and when the interview is by telephone, they do not have an opportunity for personal contact. Moreover, the candidates are certified in alphabetical order. The selecting supervisor knows only that each candidate is qualified by the promotion evaluation pattern (PEP) for the position to be filled. The order of rank on the candidate referral roster is not provided with the certificate. Consequently, the record reflected in the career brief and the interview often are the only criteria the supervisor has in making a selection decision.

The importance of the interview, then, takes on monumental proportions. The career brief presents the basic facts regarding experience and education; however, in the interview, the candidate can further elaborate on specialized knowledge and skills and the environment in which the experience was acquired. This is what the supervisor needs to discern between qualified candidates, and the candidate is the best source for the quality of this information.

In addition, LCCEP employs the Executive Cadre concept to identify Air Force logisticians with the highest potential for advancement to high-level managerial positions. The personal interview has played an important role in past LCCEP Cadre selection cycles and will continue to do so in the future. Once again, career briefs are provided to interview panel members; but the questions posed to the interviewees provide a notable opportunity to present personal experience, knowledge, and future objectives as a vital ingredient in the enhancement of Air Force logistics. How, as well as how much, information is conveyed to the interview panel weighs heavily on the score assigned to each answer.

Having established the importance of persuasive interview techniques, how are good interview skills acquired? The quest must begin inside an individual's self and flow to others through verbal communication. This translates into improved job performance and enthusiastic responses to questions concerning not only an individual's work but also the importance of his job in the entire spectrum of Air Force logistics.

Enthusiasm is contagious. It spreads to your work, and it makes you want to tell others how you feel about your job. Best of all, this is what managers are looking for in their personal interviews. A positive attitude usually produces a high score, which in turn can often lead to an exciting new job!

Source: Ray J. Twardowski, OCPO/MPKCL

Military Career Management

Looking for Another Career Pattern?

Deputy Commander for Resource Management (0096)

In July 1975, most wings throughout the Air Force were reorganized into a tri-deputy configuration. This brought about establishment of a deputy commander for resource management (DCR), AFSC 0096, a small specialty which includes 90 lieutenant colonel authorizations. The DCR is charged with the responsibility of providing logistics and financial support for the wing mission.

The DCR has functional responsibility for various wing/base activities, including comptroller, contracting, supply, transportation, and logistics plans. A logical career pattern for officers into the 0096 resource would be through the logistics (60XX, 64XX, 65XX, 66XX, 0046) or the comptroller (67XX, 69XX, 0056) career fields.

To enhance the DCR management capabilities, a deputy commander for resource management course, which is about two weeks long, was established at Maxwell AFB. This course provides new deputy commanders a comprehension of the responsibilities, resources and operational concepts, and practices of DCR organizations. It also emphasizes problems facing the DCR functions and then defines practical, on-the-job solutions to these problems. The prerequisite is lieutenant colonel with less than 12 months' experience as a DCR or assistant DCR.

Source: HQ AFMPC/MPCROS1A, AUTOVON 487-5788

Contract Management's Professional Designation: Recognition for Academic Enhancements

Contract Management, as a field of study and in practical application, touches directly or indirectly on industry marketing and purchasing functions, governmental operations, academic research and studies, non-profit organization and foundation projects, and numerous other areas.

When working within the general profession of Contract Management, individuals become by necessity well acquainted with procurement, sales, logistics, production, operations, accounting, law, industrial evaluations, and other related disciplines. However, with so many areas affecting and/or affected by Contract Management, individuals need to increase and maintain sound practical working attributes and broad professional knowledge through continuous academic training accomplishments. Because of this dedication, people serving either directly in Contract Management or in any related professional career field relevant to government contracts can now gain significant recognition for their comprehensive academic achievements (college courses or professional short courses) through the Professional Designation in Contract Management (PDCM) program, cosponsored by the Air Force Institute of Technology (AFIT), Wright-Patterson AFB, Ohio, and the National Contract Management Association (NCMA), Washington, DC.

The program is composed of the following:

(1) Satisfactory completion of eight *career (Contract Management) related courses* selected from the Defense Management Education and Training (DMET) catalog (DOD 5010.16-C). They must be at least one week in duration and four of the eight must be AFIT-sponsored. ("AFIT-sponsored" includes courses taken either in residence at AFIT or by correspondence through the Extension Course Institute (ECI), Gunter AFS, Alabama.)

(2) Satisfactory completion of NCMA-sponsored university courses. Other university courses will also be considered upon petition. The latter will be evaluated individually based upon submission of a transcript or other suitable evidence of successful course completion, as well as a synopsis, syllabus, or catalog description of the course.

As applicants complete courses, they will be continuously advised of their progress. Upon completion of the study, they will receive a personalized certificate which recognizes their professional academic developments in Contract Management applications to government contracts. Once the program requirements are met, Professor Ronald D. Culler, Chairman, Professional Designation in Contract Management, will forward the certificate through the Dean, School of Systems and Logistics (AFIT), to the applicant's commander for presentation. The Professional Designation in Contract Management will represent a significant achievement in one's professional life.

Source: Ronald D. Culler, Professor of Procurement Management, AFIT/LSP, AUTOVON 785-3944

Item of Interest

Maintenance Analysis Enhancements

Unit aircraft maintenance analysis functions are primarily responsible for performing analyses and studies as directed by the Deputy Commander for Maintenance (DCM). However, recent USAF/IG functional management inspection and USAF Audit Agency findings have disclosed several problem areas within those analysis functions which have directly affected the ability of analysis to support the maintenance management process. As a result, the Air Force Logistics Management Center (AFLMC) was tasked to develop solutions which would enable analysis to become a more responsive staff agency.

The AFLMC visited the unit level and MAJCOM analysis functions during August-October 1983. They discussed the inspection reports, determined the root causes of the different problem areas, and then formulated recommendations.

(1) Both the field units and MAJCOMs agreed that the inspection reports did an outstanding job in pointing out problem areas associated with unit maintenance systems analysis functions.

(2) The underlying causes of these problem areas were personnel selection, technical training, on-the-job guidance, relative experience level, and problems associated with the data available.

(3) The AFLMC has recommended higher prerequisites for entry into the career field, restrictions on cross-training into the AFSC, changes in the ATC course content, basic personnel management changes, a handbook for senior managers, an analysis guide, and several changes in the DMC course taught at the Leadership and Management Development Center (LMDC), Maxwell AFB AL.

In the future, these recommendations, if implemented, should enable unit maintenance systems analysis functions to become a more productive part of the maintenance management process.

SMSgt John D. Trotter
Air Force Logistics Management Center

Item of Interest

LOGCAS '84 Announced

The HQ USAF Directorate of Logistics Plans and Programs (HQ USAF/LEX) announces the Fourth Annual Logistics Capability Assessment Symposium (LOGCAS) which will be held at the United States Air Force Academy, Colorado, 7-10 May 1984. The purpose of the symposium is to provide an unclassified forum of presentation for Air Force analysts and managers involved in logistics capability assessment.

The theme of this year's symposium is "Logistics Capability Assessment: The Right Stuff?" Over the last decade, the Air Force has made great progress in developing new tools and techniques. At this year's symposium, current practices and new developments will be received with the focus: Do we ask the right questions? Do we look at the right data? Do we get the right answers?

If you wish to attend LOGCAS '84 or submit a paper for presentation, contact Major Susan Alten, AFLMC/LGY, Gunter AFS AL 36114, AUTOVON 446-4524, Commercial (205) 279-4524.

Effects of Cooperative/Collaborative Programs and Foreign Military Sales on USAF Support Capability

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Abstract

In years past, United States (US) military products and services were sold to foreign customers with very little participation, cooperation, or collaboration on their part. Such programs were essentially one way, from the US Air Force (USAF) to the customer. As the cost and complexity of weapons systems increased, and as foreign customers experienced an increasing need to develop and ensure a continuing national industrial capacity, cooperative programs became more prevalent. Today, cooperative/collaborative programs are the norm, encompassing coproduction, offset, technology transfers, and economic issues. The combination of normal foreign military sales (FMS) and collaborative/cooperative logistics programs tends to impact overall USAF systems supportability and requires intensive planning to prevent degradation of USAF support capability.

Introduction

Since 1946, the US has been among the leaders in international arms transfers. A variety of techniques have been used, from pure sales under procedures, to outright grants under military assistance service funded (MASF) and grant aid programs.

In the last 10 years, the nature of such international programs has changed significantly. Earlier military assistance programs, whether of a sales nature or more oriented towards grants, were very much a "one-way street." The US, with the technology, the industrial base, and the internal market to afford independent development and fielding of operational systems, served as the seller to allied nations. Table 1 illustrates the former extent of the US sales/grant effort.[1]

The dollar value of these military assistance programs does not fully illustrate the impact or trend in military sales progress. From 1966-1975, the US transferred approximately $3.8 billion worth of military goods to NATO, of the total $11.18 billion procured by the alliance, while buying only $1.5 billion from NATO countries. This represents an 8-to-1 balance in favor of the US.[2] At the same time, most NATO countries were moving away from grant programs and more towards pure sales. By the late seventies, the sales ratio had decreased to 5:1, due in part to increased purchase of goods by the US.[3] However, a significant part of this reduction was due to a radical increase in offset/coproduction arrangements associated with international programs. Essentially, the increasing cost of new systems, unfavorable economic trends, and political conditions caused coproduction/offset arrangements to become a standard way of doing business.[4]

With this climate of increased coproduction requirements, increased interest in furthering the "two-way street" approach to international programs, and high level of FMS activity, there will certainly be support impacts. If the emphasis on collaborative programs is sufficiently strong, a large share of a given workload would be transferred to foreign recipients. The results could well produce a decrease in the US industrial base, an increase in military dependence on foreign sources, and a resulting deleterious effect on our military capability.

Likewise, increasing numbers of politically and economically sensitive FMS programs, in concert with foreign collaborative programs, place a significant drain on US military capability. Essentially, key decision and policymakers must face a painful priority decision in the face of increasingly limited resources capabilities and finished products—who will get "first pick"? Far too often, the choice is politically driven in favor of foreign forces at the expense of our own.

In assessing the impact of foreign programs—coproduction, collaboration, or FMS—on US logistics supportability, one must be ever conscious of the need to retain an objective viewpoint. As in many areas of economic, industrial, and military endeavor, mutual benefit is derived from virtually all programs. The same is true in foreign ventures. By strengthening allies, through FMS, with technologically competitive military equipment, we relieve ourselves of at least part of the burden of providing full defense services for a myriad of diverse countries.

Similarly, by providing for continued growth and stability through coproduction/collaborative programs, we tend to provide for continued independent military competitiveness. The central issue, and one which is incredibly difficult to precisely define, is the point at which the drawbacks outweigh the benefits.

Realizing the significant benefits extant in foreign program support, this paper concentrates on the drawbacks of such programs and the actions needed to defray—or at least defer—the impact of such drawbacks. Two specific areas are addressed:

(1) Cooperative/collaborative programs - Why do we need them? Do they draw down US support capability? Is there an effect on the US industrial base? Does an adverse competition come out of such programs?

(2) Foreign military sales - Collaborative programs provide the hardware; FMS sells the hardware. Does FMS affect US logistics supportability? Is there a drawdown of US assets to support foreign programs?

Cooperation, Coproduction, and Collaboration

Since man first discovered that a thrown rock was far more effective as a weapon than a thrown fist, quantum jumps have

been made in the efficiency, effectiveness, range, and capability of weapons. One far-reaching side effect of these jumps is the complexity of, and technology behind, current military hardware. A modern fighter aircraft has behind it a complex, sophisticated, constantly improving support base of people, equipment, and parts which, taken together, form a very expensive, very advanced (and advancing) system. The two major characteristics of this system are the technological advances required to remain competitive (whether militarily or economically) and the expense required to maintain the technological edge.

Technologically, there is an at least perceived need to stay ahead—to make a fighter that will fly farther, higher, faster, and loiter longer than anyone else's. Thus, very strong lightweight composite structures and highly sophisticated avionics, fire control, and flight control systems were developed to allow today's F-15 and F-16 aircraft to be among the world's best. However, the unit flyaway cost, in double-digit millions of dollars, is only part of the cost of this capability. Expensive enough as outright purchase may be, there is a continuing requirement for manufacturing/engineering support, spares, support equipment, and a whole range of similar operating and support costs.

The net result is a market which is much too expensive and exclusive for individual customers. Acquiring military hardware has become so expensive that few can afford to produce or acquire it individually. Thus, most such nations will routinely expect coproduction offset as a condition to program consummation.[5]

US MILITARY ASSISTANCE TO NATO 1946–1976

($ MILLIONS)

COUNTRY	GRANTS	FMS CREDIT	OTHER[1]	GRANT[2] TERMINATION
BEL/LUX	1246.0	7.8	21.5	1965
CANADA			13.0	1961
DENMARK	617.8	–	22.3	1974
FRANCE	4153.1	80.4	315.1	1965
FRG	901.0	–	38.4	1964
GREECE	1629.4	450.5	904.4	–
ICELAND	NONE			
ITALY	2290.3	0.3	254.7	1973
NETHERLANDS	1217.2	2.2	65.3	1965
NORWAY	893.9	–	50.0	1967
PORTUGAL	326.4	–	38.3	–
TURKEY	3240.3	310.0	1139.6	–
UK	1034.5	–	73.0	1972

[1]Includes transfers from excess stock and other grants.
[2]Indicates the date at which grant assistance was terminated. Some countries continue to receive such assistance in some form.

Table 1.

Coproduction/cooperative/collaborative programs represent the means by which the high cost of military hardware is offset. The need for such collaborative programs, however, goes far beyond just the procurement value of weapons. Many countries see such programs as vehicles for gaining economic benefits and advancing their national objectives. Nations are thus driven by the need to:

(1) Satisfy operational requirements.

(2) Make technological progress.

(3) Maintain a broad defense technological base, industrial capability, and skilled labor force.

(4) Satisfy national economic imperatives (maintain employment levels).[6]

Collaborative programs have, in fact, become so important to many countries that some buyers (recipient countries) will present compelling reasons in favor of coproduction.[7] In fact, a consistently repeated report in the F-16 community is that, if the US had not offered significant coproduction offset, the European countries would have opted for the French competitor. Without judging the accuracy of the report, its very existence is indicative of the intensely political surroundings of international cooperation. Participants, forced to collaborate from an economic viewpoint, insist upon a comprehensive return proportionate to their inputs.[8]

What this means to the US is that it directly impacts upon military support capability. Such impacts are very diverse in nature and are cumulative by the number of collaborative programs active at any given time. However, they may be grouped into the four general categories of competition, industrial base depletion, foreign dependence, and third country conflict.

Competition

Historically, the US has been the supplier of military goods and equipment for its allies. Generally referred to as the "one-way street," this situation allowed the US to retain an essentially monopolistic hold on defense industry worldwide and, as a result, retain the capability to fully support its own military forces. This monopolistic character was not harmful from the US perspective, since the size of defense purchases and the multiplicity of defense industries did indeed provide a degree of competition internal to the country. The monopolistic face only applied to the international scene.

As the nature of international programs changed and the demand for more cooperation and collaboration on the part of buying nations increased, the US and its allies were in something of a "Catch-22" situation. The US was the only supplier to which many of the allies could turn, yet the US did not really wish to give up its independent position.

Nevertheless, the monopoly began to disintegrate. Industries were required to offer coproduction offset as part of the terms of many sales and, in fact, found it necessary to do so simply to expand. In general, these coproduction arrangements required that:

(1) Some level of manufacturing activity be given to foreign sources.

(2) Technology be transferred to foreign companies.

(3) Tooling and equipment costs be subsidized or offset in other financial arrangements.

(4) Work levels be guaranteed over multiple years.

In short, countries took on resources and work that would otherwise have gone to US industries and operated in direct competition with the source of their capabilities. This competition has had a threefold effect:

(1) It has increased the demands for already scarce resources. This results in higher cost, lower output, and lessened ability for future developments in a highly technological environment.

(2) It has watered down available support. In general, too many sources tend to prevent effective support because of the inability to operate effectively in a limited market.

(3) It has tended to impact the US industrial base.[9]

Industrial Base Depletion

The defense industry is a relatively limited one, with specialized facilities, technologies, and high start-up costs. The result is that, as more companies enter the competition, the market shares are spread thinner and thinner, to the point that a relatively stable demand cannot support an increasing supply. In short, support becomes very expensive in terms of human resources and industrial facilities and capacities.[10]

This is precisely the case that exists with international collaborative programs. The licenses and coproduction arrangements required of US defense industries place abilities and capacities in other countries and companies. Unless the parent industries can expand in some other area, their net position will be reduced because of the reduction in domestic work. However, because of the limited nature of direct defense support, there are few options for expansion. Recent examples tend to support this effect:

(1) In January 1982, one of the major suppliers of F-16 components advised (informally) that he was releasing skilled workers because of the requirement to place coproduction work in one of the European F-16 countries. The result, in the company's view, was permanent loss of a highly skilled work force, major loss in industrial capacity, and a doubtful future for one of the company's support plants.

(2) In July 1982, at an overall program support review, manufacturing representatives indicated that 16 companies were suffering from rate capacity shortages and were lead time away from correcting the situation. The reason was an earlier requirement to coproduce items and a resulting inability to either justify, support, or fund needed plant capacity.

These two examples give clear indication of the depletion of industrial support capability caused, at least in part, by collaborative programs. If we are to support many combat systems, we have little choice but to go to the very foreign sources which have depleted our capabilities.

Foreign Dependence

Utilization of foreign sources, and *dependence on* those same sources, are two, often confused, but entirely different things.

Utilization of foreign sources is an accepted, rational, even desirable method of meeting alliance defense requirements, while at the same time increasing the "two-way street" concept of cooperation. It allows better integration of multinational forces, leads to greater interoperability, and tends to spread responsibility for defense and to satisfy national needs previously discussed. However, it must not be pursued at the expense of cost and "national preference" (independent supportability).[11] When it does, or when competition and industrial base depletion cause a move to foreign sources, then foreign dependence occurs.

Realizing that many of our allies have, in the past, been almost totally dependent upon the US, the question is whether the US should be dependent (to various degrees) on foreign sources. The issue involves the ability of foreign companies to provide support to the US in time of conflict. Presumably a coproduction source is located in or close to a country buying a particular system. If the area becomes embroiled in a conflict, geographically removed from the US, would support continue?

Furthermore, it can be hypothesized that a source/country has a set of priorities when entering into coproduction agreements. Assuming that two of the highest are supporting national forces and making a profit (in terms of either sales or national employment), would support of the US be high enough to ensure our continued operation? Or would other sales to third countries, at higher prices, be a higher priority?

Third Country Conflict

In negotiating collaborative agreements, it becomes an almost impossible task to ensure control of the article being coproduced/manufactured. Essentially, a foreign user operates relatively independently and is thus free to market his product within the stipulations and limitations of contractual requirements. In this light then, there have been attempts to limit the spread of military hardware including:

(1) Munitions licenses, whereby a sale to a foreign source cannot be completed until approval is granted by the US government.

(2) Letters of Offer and Acceptance (DD Form 1513S) which stipulate that a buyer may not further sell a US supplied defense article without prior concurrence of the US government.

Even with these attempts at control, the fact is that foreign nations' policies and their own profit motives make it extremely difficult to control end users. The result is a strong potential for support items and services to go to non-allied nations. Conceivably, the US could end up fighting its own weapons systems and be unable to fully support itself because of items drained to non-allied nations.

General James P. Mullins eloquently summarized the impacts of collaborative programs when he discussed the significant problems facing defense programs:[12]

(1) Critical raw materials have been scarce.

(2) Skilled workers have not been available.

(3) Hundreds of defense suppliers have vanished over the past few years.

(4) Many defense plants have or will shortly become obsolete.

Foreign Military Sales and Military Assistance Programs

Foreign military sales (FMS) and Military Assistance Programs (MAP) are two of five categories of programs currently active in the Security Assistance Program. While Economic Support Fund, International Military Education and Training, and Peacekeeping Operations are generally grant-type, specialized programs, FMS and MAP are umbrella categories which provide for cash and credit sales, and pure grants, of defense articles and services to qualified customers. Where coproduction/cooperation/collaboration lead to development and manufacture of goods (weapons systems), FMS and MAP provide the mechanisms by which such goods and services are physically transferred. (Where FMS is used in the remainder of this paper, it is understood that MAP is included.)

A basic policy of the US is to transfer military equipment to friendly countries to help them maintain their security. A concomitant responsibility in these transfers is the need to balance the benefits and risks to ensure that the transfers will fully meet US foreign policy objectives. Included is an evaluation of the extent to which proposed transfers might:

(1) Contribute to an arms race.

(2) Increase the possibility of breakout or escalation of conflict.

(3) Prejudice the development of bilateral or multilateral arms control arrangements.[13]

FMS has become big business, involving US industry in manufacturing goods and providing services; the US government, in managing programs, negotiating on behalf of customer countries, and itself providing goods and services; and coproducers acting as major, first, second, and lower tier vendors. Table 2 provides a summary of the growth and current size of these programs.[14]

With the present US policy, and the apparent lack of explicit planning to preclude adverse impact on US military capability, there is a definite potential for such impact. Much as in the case of collaborative programs, the key lies in the degree of emphasis placed on, and the priority given to, FMS programs. Also, as with collaborative programs, FMS programs are double-edged swords. On the one hand, FMS customer investment allows the US to procure and stock quantities of assets in excess of normal requirements (characteristic of Cooperative Logistics Supply Support Arrangements (CLSSA)). On the other hand, activation of programs with too little lead time and in too many numbers produces a less-than-satisfactory support posture.

There are three major elements which tend to point towards this inadequate support posture: competition, political emphasis, and support system.

FMS/MAP VOLUME

($000,000)

	FY 76	FY 77	FY 78	FY 79	FY 80	FY50-80
FMS						
AGREEMENTS	14,673	8,304	11,039	13,014	15,277	110,827
DELIVERIES	5,798	7,022	7,408	7,506	7,698	55,566
MAP						
AGREEMENTS	263.9	241.2	218.5	225.1	299.6	54,007
DELIVERIES	364.2	108.7	220.3	168.5	336.7	53,399
TOTAL						
AGREEMENTS	14936.9	8545.2	11257.5	13239.1	15576.6	164,834
DELIVERIES	6162.2	7130.7	7628.4	7674.5	8034.7	108,965

Table 2.

Competition

In the development and deployment process for any weapons system, some type of provisioning process is used to define the types and quantities of support materiel required. This process, at least in the case of the USAF, is based upon operational criteria, including operating time, number of sites, number of units per site, manning support, and transportation support. Should any of these (or other) elements perform at a level less than programmed, then the computer support base would be incorrect and overall supportability would suffer.

As a general rule, FMS requirements (excluding CLSSA) are not included in provisioning computations. Instead, items to support such programs are added after countries definitize requirements and are lead time away from delivery and therefore supportability.

Unfortunately this system does not always work as conceptually defined. When short-notice, high-emphasis programs occur, when actual program logistics factors exceed that planned, or when demands exceed the programmed requirements, then US and FMS programs compete with one another for limited resources. Even though there is a well-defined priority system intended to rank order requirements (force/activity designator (FAD)/urgency of need designator (UND)), external factors tend to modify it. Where emphasis goes to an FMS customer, the US will lose in the priority shuffle and will thus be less than fully supportable. Quite often, this priority shuffle is based upon a perceived political necessity.

Political Emphasis

There is little doubt that US arms sales and agreements have become key ingredients in the political arena. Defense materials and services, whether in delivery or refusal to deliver, are certain to be major influences in regional stability, allies' security, and furthering our own national interest. As visible as such defense goods are, it is often expedient to provide rapid response to a country's perceived need at the expense of our own needs.

There are a number of arguments supporting this approach, ranging from the size of US forces ("We have enough to absorb it") to the relief of US forces from defense responsibility ("Let Charlie do it"). In fact, such an approach could well have an adverse impact. If we accelerate a major system, we must also accelerate the support base. If one assumes a sufficient quantity of raw material on hand and a production base in operation, then the acceleration will have no immediate effect. This stems from the ability to take from current production, accelerate from future deliveries to fill the current gap, and hope to fill the future gap with future production.

Support System

As described, there is a provisioning system designed to quantify support requirements. The other part of the system is procurement of the identified items. Unfortunately, these two elements together are not sufficiently responsive to meet the demands of high-priority, short-notice programs. The provisioning system works well, given lead times to provide the quantities of items defined; and the procurement system works well, given the lead times to buy and deliver quantities of items defined.

The common element is lead time which is the amount of time, ahead of need date, that is required to specify, manufacture, and deliver an article. Hidden in the "specify" portion of that definition (which is the author's) is the administrative and slack time added to actual production time, which is needed for management purposes. Lead time is the precise reason FMS programs can have an adverse impact on US supportability. If, as too often happens, there is

insufficient lead time to buy items, and higher priority is given to foreign support, then the only reasonable alternative is to take from US stock.

The overall result of the above elements is an impact of some degree, at some time, on US supportability and readiness. Unfortunately, the degree of this impact cannot be quantified accurately. At a detailed logistics review of the total F-16 program in July 1982, an attempt was made to quantify the impact of FMS programs. Because of the limitations of available data systems, an acceptable analysis could not be made. We are thus left with a less-than-satisfactory "what if" evaluation of FMS impact.

Conclusions

Collaborative programs, of whatever form or nature, tend to have various degrees of impact on US supportability. The positive aspects of such programs help the US by minimizing defense responsibilities and support requirements in far-flung areas. On the negative side, there is a definite drawdown of the support base. The key is to quantify the impacts to gain maximum benefit. From available data, a number of specific impacts can be identified, negative and positive, from which certain conclusions can be drawn.

First, collaborative programs tend to be more expensive, with schedule and support base impacts, than do non-collaborative programs.[15] Offsetting this, at least partially, is the decrease in overall cost to the US in maintaining defense support for allies. The key issue revolves around determining the breakeven point. When does the cost of maintaining collaborative programs become prohibitive when measured against the benefit of diverting defense responsibility?

Second, initiation of widespread collaborative programs results in relatively large numbers of customers (industry, military, or governmental) competing for limited resources and finished products. This tends to degrade the support available to all users, drive costs up, and reduce overall industrial and organic capacities.

Third, the same collaborative program that results in an overly competitive marketplace also results in too many suppliers being supported by this demand. This is driven by the need to place similar work in numerous places to meet the requirements of the collaborative agreement. Ultimately, because of the watered-down workload and the tough resource competition, sources will be lost and support will suffer.

Finally, the US must face the issue of the degree of foreign dependence acceptable to routine operations and wartime support. It is practically inevitable that foreign collaborative programs will result in sole sources in foreign locations. Ramifications to our support are widespread—lead times, asset availability, priority, transportation time—and cannot be addressed in isolation. How much foreign support we can rely upon is central to the entire issue of cooperative programs.

Ultimately, the entire industrial, economic, military, and political environment surrounding a particular collaborative program must be considered to establish the viability of the program. Only after the drawbacks are fully recognized, and a conscious decision made, should one enter into full-scale cooperative ventures.

Notes

[1] Appleyard, James C., et al. "U.S. Arms Transfers to NATO-Past, Present, and Future," *NATO's Fifteen Nations* (December 1977/January 1978), p. 71.

[2] Ibid.

[3] Greenwood, Allen. "International Industrial Cooperation," *NATO's Fifteen Nations* (April/May 1978), p. 96.

[4] Rendine, Major Michael J. "Meeting the Challenge of Multinational Programs," *Concepts*, No. 4 (Spring 1981), p. 119.

[5] Ibid.

[6] Dean, Robert W. "The Future of Collaborative Weapons Acquisition," *The RAND Corporation*, P-6199 (September 1978), p. 35.

[7] Buckley, James L. "Conventional Arms Transfer Policy," *Department of State Bulletin 81* (September 1981), p. 63.

[8] Dean. "Collaborative Weapons, Acquisition: A Closer Look," *NATO's Fifteen Nations* (April/May 1980), p. 39.

[9] "NATO Standardization: Political, Economic, and Military Issues for Congress," Report to the House Committee on International Relations, Congressional Research Service, Library of Congress, Washington DC (March 1977), p. 32.

[10] Greenwood. "International Industrial Cooperation," *NATO's Fifteen Nations*, p. 96.

[11] Appleyard. "U.S. Arms Transfers to NATO-Past, Present, and Future," *NATO's Fifteen Nations*, p. 77.

[12] Mullins, General James P. "Society and the Challenge," *Air Force Journal of Logistics* (Winter 1982), p. 5.

[13] "Security Assistance Programs," Congressional Presentation, FY 1982, pp. 485-6.

[14] Ibid., pp. 516-557.

[15] Rich, Michael, et al. "Multinational Coproduction of Military Aerospace Systems," *RAND Report*, R-2861-AF (October 1981), pp. 105-110.

Most Significant Article Award

The Editorial Advisory Board has selected "The Development of a Combat Analysis Capability for the Air Force Logistics Command" by Lieutenant Colonel Robert S. Tripp, USAF, and Captain Larry B. Rainey, USAF, as the most significant article in the Winter issue of the *Air Force Journal of Logistics*.

Most Significant Article Award for 1983

The Editorial Advisory Board has selected "Air Force Logistics Strategy for the 1990s" by Colonel Harry L. Gregory, Jr., USAF, as the most significant article published in the *Air Force Journal of Logistics* during 1983.

System Design for Reliability and Maintainability

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Abstract

Air Force system planners and project officers make decisions, knowingly or not and willingly or not, that impact the lifetime reliability, maintainability, and logistics readiness of Air Force systems. The purpose of this article is to identify these decisions, determine their possible effects on systems, and introduce some of the latest technological advances in reliability and maintainability (R&M) engineering which the decision maker can use to make an informed choice.

Introduction

Strapped by funding limitations and schedule squeezes, it is easy for a program planner or system project officer (SPO) to relieve a sticky situation by making a hurried, yet well-intentioned, decision which ends up decreasing a system's reliability and increasing its repair time. This in turn lowers its operational readiness and causes untold grief to the logistics counterpart. Sound farfetched? Of course, no responsible military or civilian member of the Air Force or Air Force contractor would deliberately jeopardize the reliability, sustainability, or logistics readiness of a defense system. However, in one way or another, that is exactly what is happening because of some hasty decisions made during the system planning process and early design.

Some decisions can be clearly labelled as "R&M decisions" whereas others, better described as "program decisions," are later discovered to impact R&M significantly. This article then identifies some of the major decisions affecting R&M which must be addressed during system development and describes possible ramifications of a "wrong" decision. In addition, a portion of my commentary is devoted to an explanation of various R&M management techniques and guidelines available to assist the decision maker.

All programs must share the common problems of austere funding and tight schedules. Thus, the decision process usually boils down to funding priority items only. In R&M, no one priority list exists because each program is unique, but it is possible to conceive a listing of the most cost-effective R&M tasks. At the 1981 Air Force Systems Command (AFSC) R&M Workshop, a Design Engineering Emphasis Panel, comprised of 25 Air Force R&M personnel representing major programs, depot operations, policy, and research and development interests, ranked the most cost-effective R&M tasks as:

Reliability	*Maintainability*
1. Parts Derating	1. Accessibility
2. Parts Selection and Control	2. Testability
3. Failure Analysis & Corrective Action	3. Logistic Supportability
4. Parts Screening	
5. Burn-In	

This article will only discuss Reliability, tasks 1 and 2, and Maintainability, task 2.

In another case, Rome Air Development Center (RADC) R&M specialists compiled a list of systems labelled "reliability successes" (defined as field reliability exceeding the requirement) and "reliability failures" (field reliability much less than the requirement) and discovered the following ingredients in each category:

Reliability "Successes"	*Reliability "Failures"*
Meaningful Reliability Requirements	Complex Systems
Reliability Program Emphasis by Air Force and Contractor	Rigorous Environmental Requirements
Excellent Parts Control Program	Routine Reliability Program Emphasis
Excellent Test Program	Off-the-Shelf Hardware Mandated
	Software Problems

Most of these factors can be controlled by the Air Force program manager and his reliability specialist, but they must be considered early in system planning and design.

System Planning

Establishing System R&M Requirements

At the onset of a program, even prior to design, decisions are made which dictate the entire R&M philosophy of the system. For example, system R&M requirements are established, usually by the potential using organization, and these numbers (or variations of them) stay with the program forever. They dictate the R&M design of the system; are used for comparison with later predictions; serve as the basis for reliability demonstration testing; are compared to observed field R&M values; and, oftentimes, are used as the determining factor in assessing the success/failure of the entire program. Unfortunately, the user or staffer who derives the requirement may not be R&M conscious and may therefore be unaware of its implications. For example, if a mission element needs statement (MENS) or program management directive (PMD) specifies a 150-hour mean time between failure (MTBF) requirement, what is meant by "failure?" Does it count only hardware failures the way system reliability predictions do? Are software errors that result in system outages included? Or, is 150 hours the minimum MTBF expected by the user regardless of the cause of system failure? In maintainability, a requirement for mean time to repair (MTTR) usually does not include time to locate spares or downtime due to human error or software error. Yet, these occurrences produce as many problems for a field commander as hardware failures. The point is—if a program manager requires a 150-hour MTBF using all possible causes of failure, then the specified MTBF should be so stated to avoid any misunderstanding.

Figure 1, for example, shows a case where a 150-hour MTBF is satisfied yet, due to a lack of understanding and

communication between the user and the developer, the user is saddled with a system which is on-the-air for only an average of 75 hours at a time. The figure also shows actual Air Force D056 field data collected on an avionics system for a total of 1,740,000 system operating hours.[1] A total of 23,193 maintenance actions were logged during this period resulting in a mean time between maintenance actions (MTBMA) of 75 hours. This is the real world number; this is the "reliability" the user is living with every day. He is disgruntled because the requirement was for twice that number. But the developer looks at the situation differently. After all, the contractor showed via a reliability prediction that the system design could achieve at least a 150-hour MTBF and the *actual failures* (hardware only) logged were 10,431; thus the MTBF of the system is 167 hours, surpassing the requirement. The confusion stems from the fact that, of the 23,193 total maintenance actions, 2,188 were found to be no defect (no identifiable reason for outage); 2,966 were removed to facilitate other maintenance (RTFOM) (not failures); 4,911 were actually caused by other on-aircraft maintenance actions; and 13,128 were actually labelled as failures. However, of the 13,128 failures, 900 were induced and, of the remainder, 1,797 were solved by adjustments. That leaves only 10,431 considered as relevant failures, resulting in the 167-hour MTBF.

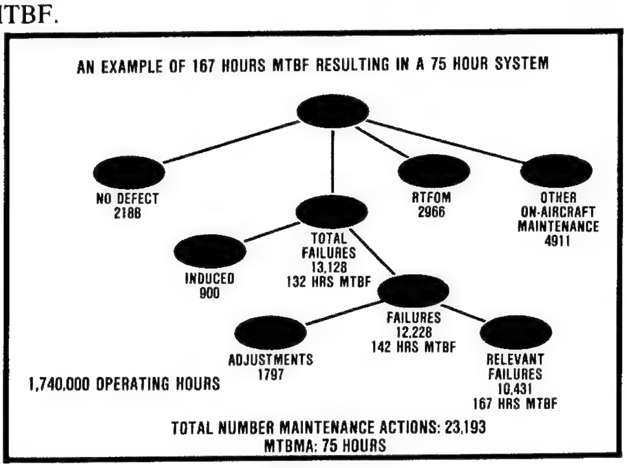

Figure 1.

Of course predicted reliability does not correlate well with field experience! Each is based on different definitions of failure as this example clearly shows. There are other reasons for differences between predicted and achieved reliability as shown in Figure 2 and described in Note 1, but the definition of failure reason seems easiest to solve.

Once a completely understood requirement is established, the methods used to meet the requirement must be determined. The first task is to determine what type of acquisition strategy to use—military design or commercial off-the-shelf, or some combination of both.

System Acquisition Strategy

Program management directives and other DOD/USAF documentation require program planners to consider using existing military hardware in formulating their new developments and to make extensive use of applicable commercial off-the-shelf equipment. The initial cost and time savings gained through the use of any existing hardware are obvious and cannot be disputed. However, prior to wholesale acceptance of this philosophy, a system planner or program manager would be wise to evaluate some of the ramifications of this approach, especially the use of commercial equipment in Air Force systems.

MAJOR REASONS FOR THE DIFFERENCE BETWEEN PREDICTED AND ACHIEVED RELIABILITY

1. FALSE REMOVALS
2. DEFINITION OF FAILURE
3. MAINTENANCE-INDUCED FAILURES
4. ENVIRONMENT
5. CONFIGURATION CHANGES
6. SPARE PARTS

Figure 2.

Surely there exist examples of commercial technology successfully used in selected military systems. Commercial computers, communications equipment, and power supplies, for instance, are part of military systems operating in benign military/environmental applications. The danger lies in the indiscriminate use of off-the-shelf commercial equipment in military applications merely to save acquisition time and/or cost without regard for any possible adverse effects of that decision on logistics readiness. The program manager must ask questions, such as:

(1) Is the commercial equipment designed to withstand the military environment expected in normal operational use (temperature, shock, vibration, humidity)?

(2) Is configuration management critical? What happens if the manufacturer changes designs or parts used in the equipment?

(3) Are spare parts available? If so, from more than one supplier, or will the government be locked in to one company?

(4) Are maintenance manuals available?

Certainly any decision process regarding the choice of commercial off-the-shelf or military equipment must consider the operational factors that may be affected. It is also clear that the impact on these respective operational factors will be different for various environments. The appropriate strategy for a particular acquisition situation becomes a case of determining whether the life cycle cost savings outweigh any risks that have to be absorbed.

In an important RADC-sponsored study,[2] a risk assessment approach was derived in which the most important operational

OPERATING FACTOR WEIGHTING

FACTOR	IMPORTANCE WEIGHT	RISK WEIGHT MILITARY	RISK WEIGHT COMMERCIAL
PROCUREMENT SCHEDULE	10	8	2
RELIABILITY & QUALITY	10	4	9
MAINTAINABILITY	7	2	8
PERSONNEL SAFETY	10	4	8
TRAINING/PUBLICATIONS	7	4	8
SPARES PROVISIONING	6	5	6
CONFIGURATION MANAGEMENT	6	3	7
NON-STANDARD PARTS	6	3	10
SPECIAL HANDLING	6	5	6
INPUT POWER	6	2	7
ELECTROMAGNETIC COMPATIBILITY (EMC)	8	4	10
DATA RIGHTS	3	2	10
SIZE & WEIGHT	8	1	7

Figure 3.

factors are identified and weighted according to their importance to the success of a radio receiver/ transmitter in an airborne inhabited fighter application. Figure 3 lists the 13 factors deemed important in the program and their respective weights (1-10). Each weighted operational factor is then assigned another weight (1-10), quantifying the risk of achieving success with respect to the factor, and the product of the weighted operating factor times the risk yields an operational risk assessment as shown in Figure 4. In this example, the commercial off-the-shelf strategy represents a calculated operational risk of 684 versus 356 for a military design, thus amounting to a 92% greater risk. For a complete analysis, this difference in risk should be compared to the potential for life cycle cost savings.

OPERATIONAL RISK ASSESSMENT

ALTERNATIVE	RISK
MILITARY DESIGN	356
COMMERCIAL	684 (92% Greater Risk)

Figure 4.

If some part or all of an Air Force system is comprised of off-the-shelf components, a definite need still exists for an effective R&M program. The selection of ruggedized versions of the equipment is advised since it increases chances of survival in a military environment. Then, reliability allocation to the lowest practical level should be made and, if possible, a stress analysis reliability prediction performed. Other, less detailed prediction procedures also can be used (ballpark estimation method). A failure mode and effects analysis, in which the effects on module/subsystem/system performance are determined for various parts failures, is needed to assess the chances of complete system shutdown in the event of unit or board failure. Extensive reliability and maintainability testing, preferably under operational conditions, is also required. And consideration should be given to a contractual maintenance warranty in which the contractor is responsible for maintaining the system and providing spares.

It is important to note that the choice of the most appropriate acquisition strategy must be done on a case-by-case basis. The program manager should use experienced R&M engineers to help identify critical factors and systematically derive the optimum acquisition plan.

After requirements are established and the acquisition strategy chosen, the system design process starts and tailored, affordable R&M program tasks are chosen. There are many R&M program tasks the acquisition agency can require a system contractor to perform as described in MIL-STD-785B, *Reliability Program for Systems and Equipment - Development and Production*. Some tasks start early in design while others are applicable during development and production testing. Most R&M program activities are tailored to specific program requirements and all cost money. The question is: Which R&M program tasks are applicable during design *and* have a major impact on R&M without excessive price tags? Favorable R&M tasks and common ingredients of successful R&M programs were listed earlier in this article.

System Design

Parts Selection and Control

If you agree that "Systems don't fail - parts do," then you believe an Air Force system is only as reliable as the parts that are used in it. The system program manager usually must decide between using nonstandard, nonmilitary-approved, commercial devices in his system or military-approved devices purchased to a military specification, or some combination of both. His decision will impact the system's operational availability and logistics readiness, but these considerations may be overshadowed by more immediate funding and schedule constraints. It is easy to allow usage of readily available, inexpensive commercial devices because they will undoubtedly satisfy R&M development requirements. It is difficult to insist on usage of military-approved parts under pressure of schedule delays due to quoted long delivery dates and higher costs to pay for the extra screening and testing dictated by the military-specification system, especially if the benefits of this hard-to-make decision will not be realized until the system becomes operational and is transitioned to a using agency. **But, it has been shown that extensive usage of commercial piece parts locks in the Air Force to a particular supplier and his prices, and could cripple the operational readiness of a system if the supplier decides to abandon that particular product line.** Also, most commercial devices do not meet environmental, radiation, and/or stress conditions encountered in military operating and storage conditions. Reliability suffers and, more importantly, system availability can be seriously degraded. In those cases where the military system is operating in a benign environment or its function is not critical to safety or mission success, then use of commercial technology may be justified. Even in critical mission functions and severe environments, it may not be possible to use 100% military parts since some circuits may be available in commercial versions only. In those cases (which represent the majority of Air Force applications) the program manager should insist on establishing a strong parts control board (PCB) or parts advisory group (PAG) to review the contractor's preliminary parts list. Approximately 90% to 95% of the electronics of a typical Air Force system can be handled with known technology or military-approved parts. The PCB or PAG should emphasize the use of proven parts, materials, and processes where possible and only military-approved nonstandard parts where necessary. Air Force systems should not be the "proving grounds" of new technology. New device technological advances are essential, but their judicious application in Air Force systems is mandatory.

An effective parts control activity in a system R&M program requires that knowledgeable parts engineers be employed by both the US Air Force procuring organization and the contractor. The system program manager can request the assistance of government parts specialists such as the Military Parts Control Advisory Group (MPCAG). MPCAG, located at the Defense Electronic Supply Center, Dayton, Ohio (for electrical and electronic parts), and at the Defense Industrial Supply Center, Philadelphia, Pennsylvania (for mechanical parts), is a DOD organization which provides advice to the military departments and their contractors on parts selection. The Air Force manager may also use RADC's microcircuit reliability assessment program (MRAP) and semiconductor reliability assessment program (SRAP). These listings are

maintained by the Reliability Analysis Center at RADC and contain information on the status of all phases of microcircuit and semiconductor specification. RADC updates the MRAP/SRAP data base continuously as new device types are selected for listing on the Qualified Products List and as the status of existing devices changes.

A major portion of system failures occurring in operational use is due to parts failures. Figure 5 shows a comparison of the number of system failures occurring in a particular radar due to parts versus those related to design and manufacturing. During early life, the split between parts and workmanship failures is about equal but, as the workmanship problems are discovered and repaired and design problems are ironed out, mostly parts failures remain. Since field repair cost estimates have been quoted as falling between \$5,000 - \$15,000 per repair, it is desirable to start a program with reliable parts at the outset. A firm commitment to use military-approved devices where applicable in design will lead to improved readiness at reduced costs.[3]

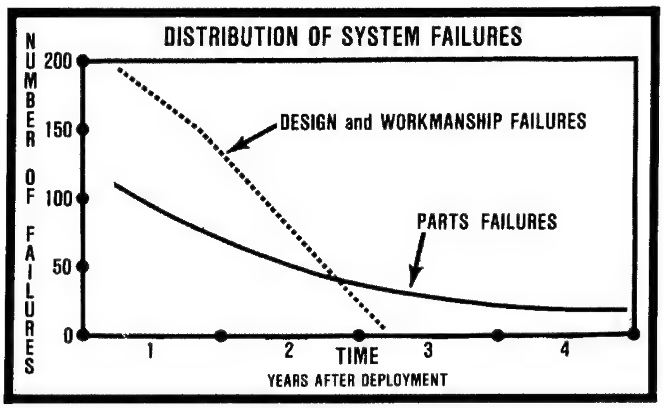

Figure 5.

Parts Derating

Sharing a top spot with parts selection and control in an R&M priority list is parts derating. Derating is defined as the practice of reducing the electrical, mechanical, or environmental operating stresses below the maximum levels the part is capable of sustaining. It can be applied to electrical, mechanical, or electromechanical parts, in each case resulting in increased lifetime for the particular part.

It is generally recognized, in accordance with the laws of chemical and physical degradation, that increasing the electrical, thermal, and mechanical stresses on electronic parts will decrease either the time required to accumulate a given amount of degradation or increase the time-to-failure. Conversely, decreasing these stresses will prolong the time to achieve a specified level of degradation and/or will reduce the probability of catastrophic failure, thus improving reliability. Derating limits the stresses on electronic parts to levels well within their specified or proven capabilities and, in so doing, further enhances reliability. Even the best parts, when operated at maximum rated stress levels, do not have low enough failure rates to meet reliability requirements of modern complex systems. A major contributing factor in the success of many electronic systems has been a conservative design approach incorporating substantial derating of parts. Derating will compensate for variability of part longevity among parts which comprise a purchase lot. It provides a margin of safety should questionable devices survive incoming inspection and screening tests. It also provides added protection from systems anomalies unforeseen by the designer.

The AFSC policy on derating directs the inclusion of proven derating requirements for all classes of devices and requires verification by analysis and measurement. The policy is mandatory for all advanced and full-scale development programs and is strongly recommended for incorporation into current contracts.

At present, there is no recognized standard for derating and there is not a large amount of published literature on derating methods or practices. Fortunately, RADC just published RADC TR 82-177, *Reliability Parts Derating Guidelines,* containing derating guidelines on 74 part types in 12 categories. This document allows an Air Force system reliability engineer to compare a contractor's proposed derating criteria with the recommendations in the Guidelines. Although it does not restrict design flexibility by mandating levels of derating, the Guidelines provide an accumulation of data obtained from a variety of military and industry sources, thus representing an unofficial consensus on derating levels.

Maintainability/Testability

In addition to reliability, the program manager must also be concerned with maintainability. The purpose of a maintainability program is to improve the availability or operational readiness of a system, reduce its maintenance manpower requirements, and minimize its life cycle costs. Maintainability requirements, like those of reliability, are important since they can dictate design; influence skill levels of the maintenance needed; and, of course, directly impact the logistics needs of the system. In fact, decisions made early in a program, such as choosing between using new military designs versus taking commercial off-the-shelf units, will affect maintainability. Emphasis on maintainability during the design phase allows consideration of important factors; for example, using standard and proven designs and components, fail-safe features, adequate numbers of well-placed test points, and worst-case design techniques.

An equally critical factor in our discussion lies within a subset of maintainability called equipment/system testability. Testability is an equipment/system attribute which addresses a capability to accurately detect and locate failures. It impacts both the time and maintenance duration needed for fault detection and fault isolation (FD/FI), activities which usually consume more time and resources than all other corrective maintenance actions combined. Thus, the testability characteristics of a system drive its maintainability characteristics and significantly affect operational readiness.

An early commitment by the Air Force systems manager to a strong maintainability/testability program will ensure the following:

(1) *Testability requirements are established based on operational requirements.* The quantitative testability requirements should be based on expected numbers and skills of operating and maintenance personnel, and be consistent with constraints imposed by the logistics system. Mission duration, operating environment, storage limitations, distance from supply source, etc., are factors influencing the testability requirement. For example, a stiff requirement limiting false alarm rates may be absolutely necessary in one instance, whereas a less-restrictive (and less costly) requirement may

suffice in another situation. Overspecification must be avoided because of obvious cost ramifications, but the depth of testability specified must be adequate to avoid subsequent redesign because of costly field test and maintenance complexities.

(2) *A design for optimum mix of built-in-test (BIT) and external test equipment (ETE) is selected.* Costs of development, acquisition, and support are directly proportional to the amount of new test equipment and test devices required by the system. Therefore, new test equipment and the range and depth of interface devices and software should be minimal. Yet, excessive use of BIT circuitry could result in added acquisition costs, reduced reliability, and added weight. Some mixed combination of BIT and ETE should be used in the proper amount to take advantage of the benefits of each approach. "BIT dominant" designs ease the burden on the operator, are fast, permit probing of inaccessible circuitry, and are performed on-site. "ETE dominant" designs increase the number of parameters that can be tested, reduce initial hardware cost, allow human decision making, and do not add weight or complexity to the design.

(3) *Testability responsibilities are identified.* Both the government and contractor focal points for testability need to be identified, and each role in the overall program process must be understood. The contractor's testability engineer must establish and maintain an effective testability program that is an integral part of the overall design effort. Close interface must occur with R&M engineering, logistics, support and test equipment, design engineering, human factors, and other related special ties. In all interfaces, the testability engineer should be prompt, active, and assertive.

Is testability worth it? Consider Figure 6 which shows the cost-to-test of a printed circuit board (PCB) designed without testability considerations versus its testing cost after redesign for testability. As fault detection requirements increase, the testability cost savings also increase. At 94% fault detection, the cost savings between the two designs are significant. At 95%, only the PCB designed for testability meets the requirement. Also, the testable PCB requires fewer test patterns and less testing time. The board designed without testability required 4,580 test patterns and 78 seconds to detect 92.2% of all possible faults. The board redesigned for testability required 1,449 test patterns and 28 seconds to detect 100% of all possible faults.[4]

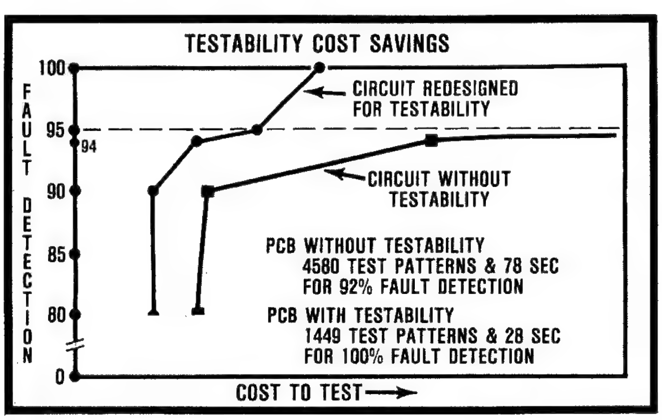

Figure 6.

Conclusions

Early emphasis on reliability and maintainability by a program manager and consideration of the impact on R&M and logistics of his program decisions will increase a system's operational readiness and reduce its operating and maintenance costs.

Evidence of improved reliability through design can be obtained by comparing performance of the F-4 and F-15 fighter aircraft. The F-15 program included R&M trade-off studies, using failure reporting and corrective action, reliability testing, parts control, and parts derating. As a result, its reliability (average flight hours between unscheduled maintenance actions) is more than 20% higher than the F-4 and it requires fewer skilled avionics technicians for maintenance (307 versus 218). Even more dramatic results are obtained by comparing the F-4 with the Navy's F-18 fighter which has a dedicated, intense R&M program. That program contains all the ingredients listed earlier in this article plus it commands high-level Navy attention. Its radar contains 8,000 fewer parts than the F-4 radar and its engine has 7,700 fewer parts. It uses two hydraulic pumps instead of four, has improved avionic cooling, and uses ground cooling fans. All this adds up to an expected average of 2.8 - 3.5 flight hours between failure (the F-4 averages less than one hour), a savings of 50% in required maintenance man-hours per flight hour, and an overall greater than 20% reduction in operating and support costs.[5]

Savings of this kind and subsequent increased performance do not happen by accident. The program manager's attitude toward R&M and his willingness to treat these engineering disciplines the same as cost, schedule, and performance requirements make the difference between a reliability success and a reliability disaster. High-level support of design for reliability and maintainability from DOD and USAF management was also in abundance:

(1) DOD Directive (DODD) 5000.40, *Reliability and Maintainability,* 8 July 1980.

(2) US General Accounting Office (GAO) Letter to Secretary of Defense, 31 March 1981, Reliability and Maintainability Requirements Need More Emphasis in Weapon System Development.

(3) *Corporate Guidance for Air Force Systems Command,* February 1981. Goal 9, "Superior Weapon Systems," seeks to "insure proper trade-offs are made between performance, new technology, reliability and supportability to maximize weapons systems effectiveness and minimize life cycle costs."

(4) Air Force Regulation 800-18, *Air Force Reliability and Maintainability Program,* 15 June 1982.

High-level management attention and support for R&M exists and applicable technology is available. All that is needed is the program manager's realization of R&M return on investment and the determination to use it to fullest advantage in programs.

Notes

[1] RADC TR 76-366, *Operational Influences On Reliability*, Hughes Aircraft Co., December 1976.

[2] "R/M/LCC Effects of Commercial Off-the-Shelf Equipment," MacDiarmid, Pettinato, Johnson, 1982 R&M Symposium, January 1982.

[3] RADC TR 82-87, *Stress Screening of Electronic Hardware*, Hughes Aircraft Co., May 1982.

[4] RADC TR 79-327, *An Objective Printed Circuit Board Testability Design Guide and Rating System*, Grumman Aerospace Corp., January 1980.

[5] *Executive Seminar for Product Assurance*, Defense Systems Management College, December 1981.

CURRENT RESEARCH

AFIT School of Systems and Logistics Completed Theses and Follow-on Research Opportunities

The Air Force Institute of Technology's thesis research program is an integral part of the graduate education program within the School of Systems and Logistics. The graduate thesis research program is designed to contribute to the educational mission of AFIT's Graduate Program through attainment of the following specific objectives:

1. Give the student the opportunity to gain experience in problem analysis, independent research, and concise, comprehensible written expression.
2. Enhance the student's knowledge in a specialized area and increase the student's understanding of the general logistics environment.
3. Increase the professional capabilities and stature of faculty members in their fields of study.
4. Identify military management problems and contribute to the body of knowledge in the field of military management.

Organizations that have potential research topics in the areas of logistics management, systems management, engineering management, and contracting/manufacturing management may submit the topics direct to the School of Systems and Logistics, Air Force Institute of Technology (Major Donald L. Brechtel, AUTOVON 785-3944/3809).

The graduate theses listed in this article were completed by Class 1983S of the Air Force Institute of Technology's School of Systems and Logistics. AFIT Class 1983S theses are presently on file with the Defense Logistics Studies Information Exchange (DLSIE) and the Defense Technical Information Center (DTIC).

Organizations interested in obtaining a copy of a thesis should make the request direct to either DLSIE or DTIC, not to AFIT. The "AD" number included with each graduate thesis is the control number that should be used when requesting a copy of a thesis.

The complete mailing addresses for ordering AFIT graduate theses from DLSIE and DTIC are as follows:

DLSIE
U.S. Army LMC
Ft. Lee VA 23801
(AUTOVON 687-4546/3570)

DTIC
Cameron Station
Alexandria VA 22314
(AUTOVON 284-7633)

CLASS OF 1983S THESES

Captain Peter L. Woodward — ADA134409
An Analysis of the Management of Funds for Risk and Uncertainty in the Department of Defense

Captain Joseph C. Benner — ADA134280
Captain Peter M. O'Neill
A Q-Gert Analysis of the Effect of Improved Automatic Testing on F-16 Aircraft Availability

Captain Stanley J. Collins — ADA134951
Captain Charles G. Carpenter
Air Force Logistics: A Historical Perspective (1940 to 1983)

Captain James R. Van Scotter — ADA134391
Predictors of Success in Air Force Institute of Technology Resident Master's Degree Programs: A Validity Study

Captain Michael J. Snedeker — ADA134393
A Model for Determining the Cost of Giving or Withholding a Desired Assignment from a Rated Officer with Six to Eleven Years Service

Captain Paul S. Killingsworth — ADB07731L
A Cost Model for Tactical Missiles

Captain William T. Marsh — ADA134949
Effectiveness Measurement in the Marine Corps Real Property Maintenance Activity

Ms. Eilanna S. Price — ADA134362
Aircraft Contractor Logistics Support: A Cost Estimating Guide

Captain Victor M. Helbling — ADA134363
Microcomputer Software System Development: Suggested Revisions to Mil-Std-1521A for Cost-Effective Acquisition of Custom Software Through Software Engineering

Captain James D. Lyon — ADA134390
An Evaluation of the Pavement Condition Index Prediction Model for Flexible Airfield Pavements

Captain Michael S. Leutze — ADB077717L
Captain Joseph R. Rine, Jr.
An Analysis of Three Different Management Approaches for the F-15 Weapon Systems Logistic Support by Japan, Israel, and Saudi Arabia

Captain Richard D. McKnight — ADA134950
Captain Gregory P. Parker
Development of an Organizational Effectiveness Model for Base Level Civil Engineering Organizations

Captain Robert J. Vaughn — ADA134961
The Effects of a Quality Circle Intervention on Four Behavioral Outcomes

Captain William M. Duncan ADA134392
Computer-Aided Design Applications for the Base Civil Engineering Technical Design Section

1Lt David A. Humphrey ADA134418
Profiles of Successful and Unsuccessful Graduate Engineering Management Students

Captain Collin F. Flynn ADA134337
An Application of the Job Characteristics Model to Selected Strategic Air Command Aircraft Maintenance Career Fields

Captain Clinton L. Campbell ADA134380
Reliability Growth Programs of Major Weapon Systems in the Aeronautical Systems Division

Major Kyu Y. Lyu ADA134506
1Lt Arthur E. Roffey
The Quality Circles Organizational Intervention: An Attitudinal Outcome Study

Captain Roger C. Rosenberry ADB077716L
Captain Richard J. Loewenhagen
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Captain Gary L. Gemas ADA134449
Aircraft Avionic System Maintenance Cannot Duplicate and Retest-Ok Analytical Source Analysis

Captain Joe Mariotti, Jr. ADA134955
Preventive Maintenance on Space Systems

(The conclusion of this listing will appear in the Summer issue.)

The Key to Survival: Aircraft Battle Damage Repair

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Abstract

Questions in many aircraft maintenance circles today are directed toward Aircraft Battle Damage Repair (ABDR). What is it? Who needs it? In many cases, misconceptions about this subject range from impressions that ABDR is already performed on crash-damaged aircraft every day, to all maintenance during wartime has to be ABDR.

This article looks briefly at what ABDR really is and supports the need for an expanded ABDR capability which will provide the necessary tools and equipment to rapidly return damaged aircraft to the battle. Another major key to ABDR's ability will be the training process and the manner in which it is accomplished. The entire concept of ABDR is vital if the USAF is to survive a no-notice conventional war!

Introduction

In recent years, there has been increased emphasis on the threat imposed by potential adversaries who possess vast quantities of sophisticated weapons of war. We have studied our Vietnam experiences thoroughly to determine exactly how logistics tactics used in that country could be applied to a sudden no-notice conventional war. I am sure even more logistics knowledge was gained from the swift and decisive mid-East wars and the more recent adventures of Britain in the Falklands. I am also sure that, if we gained good information from these conflicts, so did our enemies. One key issue in all these conflicts centers around repair and survival—the winners kept their planes flying. We need first-rate ABDR!

In the United States Air Forces in Europe (USAFE) command, the first few days of a conflict will be very critical. For instance, because the supply pipeline is very long when it comes to aircraft spare parts, replacement aircraft, and augmentation forces, we must make do with what we have in place. The Russians apparently recognize this and, according to a leading analyst of Soviet military affairs, are developing newer blitzkrieg plans of attack. Christopher Donnelly, a senior analyst at the Soviet Studies Research Center, Royal Military Academy, Sandhurst, England, also claims that Soviet plans include using division-sized formations, backed up by armor, artillery, missiles, helicopters, and massive fighter aircraft support. They plan to thrust at a very high speed into the rear of the North Atlantic Treaty Organization (NATO) defensive belt on the first day and thus effectively win any new European war in three to four days. Mr. Donnelly further stressed that much of the Soviet army's latest equipment has apparently been designed to fit into the new concept.[1]

Therefore, without an effective capability to rapidly repair battle-damaged aircraft, the theater commander can expect to lose a significant number of sorties due to damaged aircraft awaiting repair. Several studies have been made on projected aircraft attrition rates, but have varied because of assumptions. However, some worthwhile figures used to emphasize attrition rates are the sortie comparisons made for two A-10 squadrons of 48 aircraft operating in central Europe. When looking at an aircraft destroyed rate of 3% and an associated damage rate of 13%, without ABDR capability, a loss of 177 sorties, or 23% of a total 777 sorties, would occur. The total sortie number is what would be theoretically available over a 10-day period. If ABDR capability is available and half of the damaged aircraft could be fixed in 6 hours and the other half in 18 hours, we gain 114 sorties, or 82% of the sorties that could have been lost were saved. This also means that repairs are accomplished on about 12 aircraft a day for the 10-day period. If higher attrition and damage rates are assumed, even more dramatic numbers of mission losses could occur. A recent Hq Pacific Air Force (PACAF) study showed that ABDR had the greatest influence on sortie surge capability during the first five days of a conflict.[2]

The large attrition rates show then that a maximum ABDR capability must be developed to support a wartime tasking. This is an organic unit capability with specialized ABDR augmentation support from the Air Force Logistics Command (AFLC) combat logistics support squadrons (CLSSs). However, the unit in-house capability will be the most important factor in the first few days of war.

Ingenuity will play a large role in ABDR assessor techniques and the actual repair process. Every battle-damaged aircraft will probably require a different repair approach. The actual repair is also where ABDR differs from normal maintenance repair actions. The normal maintenance repair includes removal and replacement of damaged components and tubing. Then permanent repair of the structure and sheet-metal is accomplished. The ABDR approach, on the other hand, is to repair tubing and wiring on the aircraft if it is easier and faster, and get away from the normally high, time-consuming remove-and-replace actions. The sheet-metal repair will probably have a different appearance than the normal permanent repair. For instance, an external reinforcement stringer may be placed across a patched area. This means it was quicker and easier to provide the necessary structural repair strength on the outside rather than accomplishing the tedious and time-consuming repairs inside. This action would only be determined after all factors were considered; e.g., type aircraft, mission to be flown, strength of the repair, location of the damage, and critical need of the aircraft. The repair may not be pretty, but it will provide a structurally sound aircraft the opportunity to return quickly to the battle, for at least one more effective combat sortie.

Ideal ABDR Program

Now that we understand exactly what ABDR is and realize that it is essential, we need to develop the basic elements

required to reach a plateau where an enhanced ABDR capability exists. The ideal ABDR program must include an abundance of kits, trained personnel, adequate technical data, additive spares, and facilities for survival.

Kits

What exactly do we mean by kit requirements? In this case, the kit consists of all tools and materials (bench stock) needed to cover any possible aircraft damage. Specifically, this includes rivets, self-flaring tube fittings, wire, wire splices, tubing, sheet metal, screws, nuts, bolts, tape, adhesives, etc. All this hardware is necessary in sufficient quantities to perform repairs on several damaged aircraft. The exact type of necessary hardware will have to be adapted to the particular aircraft being supported. Also, the kit must contain the necessary hand tools and power tools (both electrical and air) required to make sheet-metal repairs. Individual specialty toolboxes should be constructed to cover, at a minimum, pneudraulics, electrical, and integrated-electronics repair. The AFLC CLSSs are a good starting place to obtain a general listing of tools and materials necessary to support ABDR.

Another necessary part of the kit is the requirement that it be self-supporting. The manual sheet-metal hand tools are necessary but, for speed, the power tools are needed. To have power, the kits need a portable air compressor and generator which can sustain up to four power tools at one time. The kit also contains all ABDR technical data, both general and for specific aircraft.

In order for the kit to be more practical, it is made completely mobile. One of the easier adaptable trailers that can be used is the F-2 munitions-trailer chassis. Sheet metal is then adapted to construct a large box that mounts on the trailer. The box contains doors that open; shelves for storing the sheet-metal hand and power tools; bench stock bins; and storage compartments for power cables, air hoses, droplights, sheet metal, toolboxes, etc. To further ensure mobility, trailer-towing capability should be retained. Being mobile ensures that the needed tools and equipment can be rapidly positioned on any portion of the flight line. Also, the mobile kit is easily loaded on all cargo aircraft without needing pallets or forklifts and is self-supporting when shipped to forward operating locations (FOLs).

Procedures for tool control must be practiced before in-shop inventory control can be adopted. It does no good to rapidly repair an aircraft if it is subsequently destroyed because tools were not accounted for and left in the aircraft.

There is no magic number of kits needed. This is determined by the number and type aircraft; wartime mission; anticipated attrition rates; and, in some cases, consideration of a more than just average war scenario.

Training and Technical Data

Kits are useless unless there are people trained to use them. Why should it be so important or difficult to train maintenance personnel to perform maintenance? The first step in training must be to overcome what all maintenance people have been previously taught—not to deviate from technical data and to follow the book step-by-step. Now, ABDR comes along and gives methods of repair but does not rule out ingenuity and innovation in completing a job. Therefore, because these qualities are involved, ABDR training should be given to those personnel who already know how to do it by the book. Experience is necessary before one can truly find better and easier methods to restore structural and system integrity. This usually rules out 3-level Air Force specialty codes (AFSCs) in the ABDR program.

Before a job can be accomplished, one must know what to accomplish. The assessment of damage to each aircraft is the key to any battle damage repair capability. The assessors play a critical role in the speed with which damaged aircraft can be regenerated for wartime sortie requirements. The assessors' primary tasks are to evaluate the extent of battle damage, determine the capability to effect repairs, estimate the time required to repair the damage, and specify those to be accomplished or deferred. Complete knowledge of the aircraft structure and systems operation is required; only the most qualified and experienced personnel available should be selected and trained as ABDR assessors.[3] They must be totally familiar with the aircraft's mission essential subsystems list (MESL) because in some instances the quickest repair might be no repair at all.

Working along with the assessors will be the ABDR trained technicians. Technician training must include at least a week of formal classroom work. Assessors should also receive this week of formal training, plus a couple of extra days to concentrate on assessing. The technician, regardless of specialization, should receive the total training program and not just concentrate on his own area. The idea is to ensure that specific ABDR repairs are performed by specific specialists. That means sheet-metal damage must be repaired by a sheet-metal person if possible. However, during a conflict, the amount of work can greatly accelerate for a single specialization and trained backup personnel must be available. This is not a call for a full-blown cross utilization training (CUT) program but a call for more personnel familiar and qualified to perform ABDR.

Studies are now being performed to develop and demonstrate a computerized data base model and design-sensitive repair time estimating procedure. The completion of the combat damage repair time (CDRT) model could be extremely helpful to an assessor since it basically asks and answers a series of questions from: "What items were damaged?" to "How long will the repair take?"[4]

The hands-on portion of training must be as realistic as possible. Actual aircraft hulks should be used and the scenario should include all types of environments, to include using protective equipment and simulating repairs under chemical/biological warfare conditions. To increase realism, the actual damage repaired during training should be inflicted by using controlled explosive charges. The shrapnel produced in the actual explosion makes the assessment and repairs more realistic and shows that assessment must be carefully accomplished if all needed repairs are to be identified.

Now that we know who needs to be trained, the next question is how? Ideally, Air Training Command (ATC) field training detachments (FTDs) should provide the initial ABDR training for 5-level personnel. The unit then would develop a capability to conduct annual refresher training through the classroom method or by the use of exercises. A mobile kit should be used during the hands-on training so personnel will be familiar with the available tools and equipment. The development of a course outline and plan of instruction is, of course, a necessity, but the main ingredient for training is using ABDR technical data that will be applied during actual repairs on combat-damaged aircraft.

Two other training or informational areas are necessary in ABDR: to conduct an introductory course for aircraft maintenance officers at Chanute AFB, Illinois, and to build a comprehensive briefing for all aircrews so they will know the program, type maintenance to expect, and their role in systems failure identification.

Therefore, to make sure all ABDR training is tracked properly, it should be loaded into the maintenance management information and control system (MMICS). This will provide the proper controls and training forecast necessary to keep the ABDR training program current.

Additive Spares

Each aircraft should be studied from a mission standpoint to determine the most likely areas where combat damage will occur. Next, a comprehensive look at the aircraft design and systems can give us insight on what spares will be needed to support the aircraft in a combat environment. Aircraft with a wartime mission will already have a war reserve spares kit (WRSK) established. A WRSK is generally stocked to provide spares for one month of combat operations, and it is from this stock that spares needed for maintenance and combat damage repair are drawn. The decision about which components and how many should be included in the WRSK is based on failure rates during peacetime flying. In a conflict, if a high level of combat damage occurs, spares of some components which seldom fail in peacetime would not be in the WRSK, but would probably be needed to replace those which have been damaged by enemy fire. The WRSK items are normally components with moving parts, such as hydraulic pumps, engines, etc., which usually fail upon an accumulation of so many hours in service. However, what is missing from the WRSK are structured modules (wing leading edges, vertical stabilizers, outer wings). Since these are not moving parts, there is very little need to replace them as a result of flying or operational wear-out, but there is usually a great need in time of war. This means the WRSK is probably inadequate for both normal wear-out and non-fail operational items. The absence of sufficient spares in both areas shows specific planning is required in anticipation of battle damage to assure the WRSK has these items to support a real-world wartime tasking.

Facilities

To this point, we have painted a picture of trained personnel with plenty of spare parts traveling everywhere with mobile trailers and accomplishing fast, ingenious repairs. However, if we visualize a conflict in Europe, then it is reasonable to expect that we will endure serious air attacks on some of our bases. This scenario could quickly lead to no back-shop facilities to manufacture those items that are extremely difficult or impossible to make by hand on a mobile trailer. Ideally, the answer to this problem is to plan for a small, but well-equipped, fabrication shop in a semihardened facility.

The ABDR fabrication shop, because it is only semihardened, should be away from the main flight-line shop facilities. The facility does not replace the current fabrication shop but adds to the peacetime capability by being used all the time. It should contain all of the absolutely essential fabrication shop equipment. It should also be equipped with chemical and biological warfare survival capability.

When we look at ABDR facilities in a more cost-effective but less protected view, there are other options for protection. Fabrication shop capability can be achieved by using a portion of a hardened facility already in place on the flight line. The facility should be modified to contain the required power outlets and plans to provide an alternate power source if and when needed. The plans must also include the necessary fabrication shop equipment.

To make even more efficient use of available space in the flight-line facilities, fabrication shop equipment could be spread throughout the flight-line hardened facilities. This action would probably not disturb the present intended use of the facility.

Another optional solution for ABDR facilities would be to provide needed fabrication shop equipment in a hardened facility, and personnel could work the machinery dressed in the same chemical-protective clothing as flight-line personnel. The tedious shop work will be done more slowly under the dispersed and protective clothing alternative, but this option is a feasible solution to a very costly "ideal" ABDR facilities program.

Aircraft Problems

The first area which is still under development and hurting the present capability to perform rapid ABDR is the use of graphite and boron epoxy composites on some of our newer model aircraft. The use of epoxy is already firmly established in the aircraft industry. The cost of graphite epoxy has decreased to the point where it is cheaper to manufacture aircraft parts from advanced composite material in lieu of metals. The composites also have the strength of metals but only about one-third the weight. They are noncorrosive, have a fatigue life longer than aluminum, and offer a wide range of design possibilities. The need for a source of repair on advanced laminated composite aircraft structures has been recognized by the Sacramento Air Logistics Center (SM-ALC). They claim that advanced composite aircraft structure technology is only an extension of conventional aluminum honeycomb sandwich construction technology. The 10 years they have spent repairing adhesively bonded aluminum honeycomb sandwich construction on older aircraft have adequately prepared their maintenance personnel to repair advanced composite aircraft structures. The process of learning to repair graphite or boron epoxy composite structures is an easily achievable task because of their experience.[5]

Several tests and studies have been conducted over the years which investigated the durability, survivability, and repairability of composites. The F-111 boron-and-epoxy, horizontal stabilizer showed excellent ability to sustain multiple hits from .50 caliber projectiles, and F-14 graphite-and-epoxy wing box sections showed they were able to survive a 23-mm, high-explosive incendiary projectile. The repair of these areas is however another question. Peacetime field repair procedures have been developed for composite materials, but the apparent inability of all levels of maintenance to do effective rapid repairs on aircraft-structured composites is a major problem. Much of the current effort is directed at cosmetic, nonstructural repairs at the organizational and intermediate levels only with all other repairs being deferred to depot level. Problems still exist then in providing the military technician with methods, tools, and training to make composite structural repairs which will restore 100% load-carrying capability.[6]

If an air logistics center is just starting to establish composite repair techniques, and current studies agree that it is a major problem, then what chance do our field technicians have of understanding these techniques without any experience or guidance on ABDR composite repair? At present, the F-4 and F-5 aircraft are the only two that have a specific technical order developed and in the field for ABDR. Our newer aircraft ABDR technical data are still under development and, in some cases, will not be in the field until late 1984.[7]

Composites are not the only method used to make our modern fighter aircraft lighter. There are miles of electrical wiring in an aircraft, and methods have been developed and are currently used that make tremendous space and weight saving possible through the new, smaller-sized, and differently insulated wiring. The problem this presents is where a rapid splice is necessary. To go into the wire bundle may cause more problems than you can correct. The suggested method to correct a wiring problem is to run another wire on the outside of the wire bundle from one established splice or terminal area to the other and not go into the wire bundle. Some other aircraft have ribbon wiring which is just as awkward to splice. Coaxial cables present a special type of problem; they can be spliced or jumped, but this usually is inadequate. This is because the splice in turn sets up too much resistance and causes a significant drop in the already low-signal voltage carried by the wire. Wiring is an area where extensive research and development are required to make ABDR feasible.

Another area that requires the splicing ability is the tubing on an aircraft. With all the fittings an aircraft has, it would seem that this would not be a problem. A closer look, nevertheless, shows that tubing made out of stainless steel or titanium will not work using the standard, self-flaring fittings as splices. The metal is too hard to flare on the aircraft and the present shop method is to use perma-swedge to secure the fittings on titanium lines. What is really needed is a quick way to splice the stainless steel and titanium tubing without having to go through the long and tedious process of removing the line and taking it to the shop. This problem area may have already been solved by an invention now available in the private sector. Research shows there is an "H" repair fitting used for aircraft fluid systems on the market. This fitting is installed with ordinary wrenches; the five-step procedure is simple to follow and requires no training. The complete installation only takes five minutes. The repair is not temporary; once installed, no replacement fittings or maintenance is required. The fitting accommodates all tube materials and sizes. It has been tested and approved by the Federal Aviation Administration after it passed the pressure-impulse, fatigue-and-burst test requirements. The "H" repair fitting also installs within the envelope dimensions similar to those of standard flared and flareless union assemblies.[8] This is definitely the type fitting needed for our special metal tubing.

These current aircraft problems of composites, wiring, tubing, and technical data must be resolved if a rapid ABDR capability is to exist. Even though these problem areas are being studied, there is still much concern in the aircraft industry that methods must be developed to resolve them before the aircraft is mass-produced. For instance, the aircraft contractor has not identified graphite epoxy composite repair procedures for the F-18 aircraft. There are several repair concepts being evaluated by aircraft contractors; but it is imperative that procedures be identified, verified, and approved to repair in-service damage prior to fleet introduction of the F-18.[9] The ABDR technical data must be developed and published on the same time scale as normal servicing, inspection, and repair publications. Then, when the aircraft is accepted into the Air Force inventory and assumes a combat role, the capability must exist to maintain the aircraft in a combat environment. It does no good to have sophisticated quality aircraft if they cannot be kept in the air using simple and rapid repairs.

Future aircraft designers should use the A-10 aircraft as a model because that airplane is the leader in repairability features. A great deal of thought was put into this aircraft in the design stage to meet its assigned mission and help it survive against anti-aircraft artillery and small-arms fire. It has superb accessibility through the numerous doors and panels that can be opened and removed to ease the location of all damage. Panel replacement is also easier. The major structured modules are assembled as units on the A-10 and, therefore, are readily replaceable. Of particular note are the outer wings, engines, and stabilizers. They are large and exposed and can be expected to receive a high percentage of hits. The modular structure gives a repair team the option of removing and replacing the components if the repair time required is much longer than the remove-and-replace time for the module. The majority of the A-10 airframe is built from single-curvature, aluminum-alloy sheets reinforced with stringers and ribs. Repair techniques for this type of construction are relatively simple.[10]

Conclusion

In the 1950s, the US produced 1,500 new fighter aircraft per year, while in the 1960s 400 per year were completed. Our production dropped further to a low 200 per year in the 1970s. When one compares our 200 with the 1,300 the Soviets produced, the Soviet superiority equates to 15 new wings. There is more to the equation. If in fact the Soviets develop faster and more maneuverable aircraft, our present qualitative aircraft advantage would be compromised. The Soviets have also shown great improvements in radius of action and avionics systems. In addition, they are upgrading the radar-and-missile capability of their fighters and are expected to produce air-superiority fighters with maneuverability comparable to our F-15 and F-16 aircraft. If we are to remain competitive in tactical combat, we must achieve significant new capabilities in our next generation fighters.[11] Increased survivability can be one of those capabilities.

Notes

1 "Russ Blitzkrieg Plan Claimed Victory Over NATO in 3 to 4 Days," *The Stars and Stripes*, 5 October 1982.

2 *General Aircraft Battle Damage Repair Technical Order*, TO 1-1H-39, United States Air Force, March 1980.

3 Letter, Headquarters United States Air Force (LEY), Washington, DC, to all major commands, USAF Concept for Aircraft Battle Damage Repair, 18 April 1980.

4 Flowers, J. J.; D. H. Kovatch, and R. L. Day, Jr. *Aircraft Combat Damage Repair Estimating Procedures* (Dallas, TX: Vought Corporation), June 1982.

5 Brochure, The Establishment of a Source of Repair (SOR) for Advanced Laminated Composite Aircraft Structures (Sacramento, CA: Air Logistics Center), January 1982.

6 Flowers, Kovatch, and Day. *Aircraft Combat Damage Repair Estimating Procedures*.

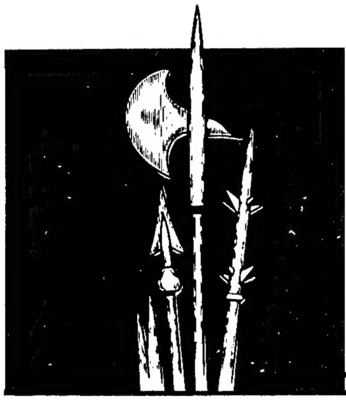
7 *F-16 Aircraft Battle Damage Repair Technical Order, Statement of Work* (Fort Worth, TX: General Dynamics), 30 August 1982.

8 *"H" Repair Fittings for Aircraft Fluid Systems* (Burbank, CA: Sierracin/Harrison), June 1982.

9 Letter, Perl, D. R. (Code 3231B). (North Island, CA: NESO), F-18 Advanced Composite Materials, June 1982.

10 *Aircraft Structural Repair Technical Order*, TO 1A-10A-3-1, United States Air Force, 20 January 1981.

11 Letter, Air Force Policy for Commanders, Office of the Secretary of the Air Force, 15 October 1982.



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LOGISTICS WARRIORS: USSR in Afghanistan

"The Soviet invasion of Afghanistan took the whole world by surprise: it was a brilliant piece of brinkmanship for which the Soviets should be awarded full marks. The Soviets had correctly calculated that the American president would not receive Western European backing for any effective action that would bring the risk of war with the USSR. After their Vietnam experience, the American people would not want American armed forces bogged down in a similar situation in Afghanistan. Also, 1980 was an election year, and Carter could not hope to be reelected if he drew his country into a shooting war.

Had Carter, with the full backing of his European NATO allies, ordered a Red Alert as Nixon had done in 1973 (without NATO allied support) and had NATO forces begun to mobilize, the probabilities are that the Soviets would have backed away and thinned out their troops in Afghanistan quickly, as they did not want an open confrontation with the United States that could escalate into a World War III. The Kremlin leaders respect strength and resolution and take advantage of weakness and hesitation. Soviet calculations and brinkmanship paid off better than the Kremlin leaders had dared to hope.

The Soviets had long been planning such a move and had been simply waiting for the opportunity. To the Soviets, Afghanistan was a crossroads for the next move towards world hegemony. From Afghanistan the Soviets can either expand south into Pakistan towards the Indian Ocean, or west into Iran towards the Persian Gulf. They will do so whenever cirumstances are favorable and the moment opportune."

From: *Tracks of the Bear* by Edgar O'Ballance.

LOGISTICS WARRIORS: General Brown on Maintenance Management Information Systems

"An example of Brown's ability to cut waste is provided by Rogers: 'A new program introduced by the Air Force was an elaborate system of data keeping at the flight-line level, designed to measure the time and effort being spent by the mechanics on various types of activity, to improve maintenance through the use of statistics. The new system had been introduced at Williams shortly before I arrived and had already started to create problems, as new systems often do.

'The trouble was that nobody paid any attention to it. The master sergeant was the only one who seemed to know anything about it. The maintenance supervisors on the line and in the shops weren't enthusiastic, and most of the mechanics were cheating on the figures. It looked like there ought to be something done about all this, because it represented a considerable investment in machinery, software, and time.

'It all began with a lot of punched card machines, and Williams was one of several bases that had been supplied with them. The equipment was presided over by a master sergeant from maintenance control. The system required that virtually all of the maintenance personnel on the base fill out what amounted to a time card each day. They were turned in every day, were processed and run through the equipment, and every day the machines produced an elaborate, impressive-looking "poop sheet."

'The master sergeant and I came up with some simple bar charts that were easier to read than all that paper being disgorged by the computers. We were trying to make sense out of all this information. We then went up to see George Brown to get his reaction. We got the kind of reception from him that one would expect. He recognized immediately the validity of our trying to make sense out of it and utilize it.

'With that, we entered a new era in maintenance record keeping. George directed me to make sure that the people under our supervision who were providing the records from which the data were compiled fully understood their responsibilities, and that proved to be the key to the whole problem. With his backing, we were able to bring all supervisors together for on-the-job training and instruction. From then on we got full cooperation from the people providing the data, instead of lip service, because they understood that the data gathering served a useful purpose and was not just another piece of make-work. We began generating meaningful data of use to all commanders.' "

From: *George S. Brown, General, U.S. Air Force: "Destined for Stars"* by Edgar F. Puryear, Jr.

LOGISTICS WARRIORS: Dien Bien Phu

"A study of the various accounts leads to the conclusion that there were two main causes for the defeat.

The first was the insufficiency of French air force resources. Stewart Menaul draws a striking comparison between what the French were able to do at Dien Bien Phu and the American and South Vietnamese performance in the siege of Khe Sanh in 1968. In this action two North Vietnamese divisions numbering over 20,000 men besieged a garrison of 6,000. The siege lasted for seventy-eight days. In that time American air force and navy pilots flew 24,000 sorties in which more than 95,000 tons of bombs were dropped on the enemy. The defenders received over 12,000 tons of supplies from 1,200 supply sorties. In Menaul's view, 'the garrison held out entirely due to the right application of air power in the right strength at the right time.' Such an effort was well beyond French capabilities.

There is general agreement that the second major contribution to the French defeat was the persistent underestimate of Viet Minh capabilities and an overestimate of their own. They could not believe that the Viet Minh could supply so large a force in such forbidding terrain; at the same time they considered that the terrain would not prove any serious impediment to their own sorties. The generals in Hanoi and Saigon were surprised by the weight of firepower the besiegers were able to bring on the fortress and by the virtual collapse of their own supply system in the last days of the battle.

Consequently the greatest measure of blame must be assigned to the staff officers who planned the operation and then, when the situation began to deteriorate, failed to call a halt and to direct De Castries to cut his way out when he still had sufficient men and ammunition.

Did the Americans and other allies learn anything from the siege? The American performance at Khe Sanh is part of the answer, but only part. For the same underestimation of enemy capabilities and overestimation of our own contributed to the early American reverses in the Vietnam War.

One of war's grim axioms is that no power ever learns from another's defeat."

From: *Crossroads of Modern Warfare* by Drew Middleton.

LOGISTICS WARRIORS: Wedemeyer on Planning

"More important than the army's size, however, was its composition. It was to contain sixty-one armoured divisions, nearly a third of the total and an altogether higher proportion than that present in the German, British or Russian armies. Wedemeyer had been introduced to the idea of mass armoured tactics at the *Kriegsakademie;* he had, like all professional soldiers, marvelled at their successful application in the 1940 blitzkrieg; he was determined that the United States should have the means to outblitzkrieg Germany when the time came. And so, unlike the British army, which was building and training a host of small specialized units for raiding and diversion, the American army, in Wedemeyer's plan, was to contain only three sorts of formation: armoured divisions, a few airborne divisions to operate with them on the blitzkrieg pattern, and a mass of infantry divisions to consolidate the gains won by the tanks. It was, in short, to be an army suitable for only one sort of operation: large-scale, tank-infantry battles on the continent of Europe. In a covering note, Wedemeyer revealed that intention and his own philosophy of battle in unequivocal terms: 'We must prepare to fight Germany by actually coming to grips with and defeating her ground forces and definitely breaking her will to combat . . . Air and sea forces will make important contributions, but effective and adequate ground forces must be available to close with and destroy the enemy inside his citadel.'

Though a citizen of the most productive nation on earth, and one with slack enough in its economy after twelve years of depression to display a breathtaking burst of industrial acceleration, Wedemeyer recognized that not even the United States was rich enough to disregard the most fundamental of all truths about strategy; that it is always a matter of choice. 'He who defends everything', Frederick the Great used to warn his generals, 'defends nothing.' 'He who attacks everywhere', Wedemeyer might have echoed, 'attacks nowhere.' The United States, though over twice as populous as Germany, could not at the same time build an army large enough to fight a major war against the Japanese, wage peripheral operations around the coast of Europe and attack the German heartland, while still manning the factories which made her the arsenal of democracy. Since all else depended on their output, there would have to be economies elsewhere. The Japanese could not be ignored; the Germans *must* be brought to battle; therefore the economies must be made in peripheral operations. But they could also be achieved by correct, early decisions about the way Germany was to be fought to a standstill while the Japanese were kept in play. A war in the Pacific must of necessity be amphibious, entailing the creation of expensive amphibious task forces."

From: *Six Armies in Normandy* by John Keegan.

LOGISTICS WARRIORS: Soviet Logistics

"The Soviet logistics system in recent years has concentrated on increasing self-sufficiency of combat units and subunits, speeding up and increasing the capacity of transport facilities, minimizing maintenance and repair problems by means of standardization, and improving efficiency of delivery to subunits through greater coordination of service and combat units.

Soviet production of military equipment has emphasized increased standardization of parts for easy repair and maintenance. For example, the PT-76 light tank chassis serves as the base for a variety of armored vehicles and missile carriers, and the T-54/55 tank chassis is used for bulldozers, bridge layers, and other vehicles. This concept also holds for small arms, such as variants of the AK model assault rifle. Small arms ammunition can be used in a variety of rifles and machineguns. Soviet arms production has always been evolutionary, with variations developed for older reliable weapons rather than throwing away old equipment in favor of completely new types. The Soviets rarely discard outdated equipment but stockpile it in strategic reserves. Standardization of parts means that many of these older weapons can be cannibalized for repair of newer ones. The net result of standardization is easier field repair and maintenance using standardized parts and techniques.

Centralized planning is the core principle of Soviet logistical support. It is maintained at all levels by the chief of the rear to achieve economy and flexibility. The priorities for resupply are: ammunition, POL, technical parts, and rations. These priorities are rigidly followed. The principle of forward distribution—i.e., higher formations are responsible for delivery of supplies to lower formations using their organic transportation—is intended to free battalion and company commanders from logistics problems. In addition, large stocks of all types are held well forward. In particular, stocks of POL are held as far forward as possible so that formations can attack from the line of march with fuel tanks full. Soviet doctrine also calls for the maximum use of captured stocks, particularly POL, although the logistics in operations planning are unlikely to depend on this factor."

"Soviet logistics do not constrain combat operations for units at divisional level and below, particularly during the initial phases of conventional combat. Transport capability is being improved at all echelons. At echelons above division, the increasing use of automated supply procedures and the introduction of material handling equipment and palletization/containerization improves the Warsaw Pact's potential to conduct more sustained conventional combat operations. The Soviets have made and continue to make siginificant gains in alleviating shortcomings they have perceived in the logistics area."

From: *The Warsaw Pact: Arms, Doctrine, and Strategy* by William J. Lewis.

LOGISTICS WARRIORS: Korea - Clothing, Food

"Logistics complexities found expression in such basic areas as clothing. For one thing, the question of US sizes caused difficulty for many smaller UN soldiers. The desirability of maintaining a single supply system for combat suggested the practicality of standardization with the clothing of the US forces. Some UN troops, again excepting the British Commonwealth, attempted to replace only their worn-out supplies with US items. In many cases, such as the French, the essential logistical problem became one of indoctrination in US clothing sizes, as well as the limitations of US depots.

There were instances of inadequacy; the onset of winter and the rapid pace of tactical situations produced much suffering despite adequate preparations beforehand. As one Argyll Highlander phrased it:

Apparently the British battle dress was not thought adequate to a Korean winter and Scots were happy that dependency on the supply system of the American divisions permitted windproof jackets and fur hats to be issued to Commonwealth division people.

But some other UN contingents needed extensive training in the use of US cold weather gear, and some US equipment simply proved too complicated for them to operate and service. This included liquid-fuel/high-pressure cooking and heating apparatus, water purification techniques and insect repellent material. UN personnel actually died from confusing fuel tablets with food or salt tablets, while immersion heaters were thought to be part of shower units, and helmet liner neckbands were mistaken for ties. Words like 'poncho,' 'shelter half,' 'cargo pack,' 'kitchen fly' and 'pile liner,' while familiar to European allies, were quite foreign to Thai troops.

World War II experience in the Italian Campaign had conditioned Korean War planners to the anticipated *cuisinerie* difficulties of the multinational force. However, food preferences and religious customs actually proved far less difficult than expected although some modifications and special rations were developed to meet the problem. ROK forces had their own prewar-designed food ration but had to draw on US stocks when shortages developed in their war-ravaged homeland. In addition, the Koreans lacked an individual combat ration when their forces deployed beyond the reach of field kitchens. This led to the use of Japanese food specialists in developing a special Korean combat ration."

From: "Allied Interoperability in the Korean War," *Military Review* (Jun 83) by B. Franklin Cooling.

"The cardinal responsibility of leadership is to identify the dominant contradiction at each point in history."

Leadership by James MacGregor Burns
(New York: Harper & Row)

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